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CONTENTS

KUBO, I., S. HORI, M. KUMEMURA, M. NAGANAWA, and J. SOEDJONO: A biological study on a Japanese edible mantis-shrimp, *Squilla oratoria* De HAAN 1– 25

HATTORI, J. and M. SEKI: A growth-study of *Hemiramphus sajori* (T. & S.) by scale and size-composition 27– 32

HOSHINA, T. and R. KUWABARA: On a new commensal copepod, *Mytilicola mactrae* n. sp. obtained from the intestine of *Mactra veneriformis* REEVE ..... 33 –35

TAKAGI, K.: Zoogeographical studies on the demersal fishes of the Tokyo Bay 37– 77

ONO, T., J. SENO, F. NAGAYAMA, and K. HIKOTA: Studies on the fat metabolism of fish. 2. Histological and chemical studies on fat and phosphorus in rainbow trout ..... 79 –87

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A BIOLOGICAL STUDY ON A JAPANESE EDIBLE MANTIS-SHRIMP, *SQUILLA ORATORIA* DE HAAN

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(Received Sep. 15, 1958)

The mantis-shrimp, *Squilla oratoria* De HAAN, "Shako" in Japanese name, is, in Japan, an important aquatic species as being available for human diet. It commonly inhabits muddy bottom of shallow waters of Japan in considerable abundance. Nevertheless only few knowledges in regard to the fishery biology of this animal is present, although KOMAI (1924 '27, and '32) on the development, taxonomy, and the spermatogenesis, SHIINO (1942) on the embryology, and KUBO et al. (1957) on the distribution in the Tokyo Bay of this mantis-shrimp, rendered excellent works.

A fishery biological investigation has been carried out by the present authors dealing with a considerable number of specimens taken from Tokyo Bay, in which a fishery is supported by this mantis-shrimp. In the present paper which consists of 8 sections are given somewhat condensed accounts of our study. Heading of the sections made in this paper are as follows:

1) Material and method
2) Size-difference by fishing ground
3) Sex-ratio
4) Weight-length relationship
5) Ponderal index
6) Spawning season
7) Mass-growth
8) Feeding-habit

Before proceeding any further the authors express indebtedness to the staff of the Fishermen's Association of Koyasu, Kanagawa Prefecture, who helped us in sampling material. It should be written in this place that the present study was supported by the grant in aid for foundamental scientific research of the Ministry of Education. Finally acknowledgments are also due to Mr. Kazunori TAKAGI for his kind assistance in various ways during the course of the present investigation, and to Akio MIURA for his kindness in preparation of the photograph used in this paper.

1. Material and method

In total 2005 females and 1600 males ranging 2.8~17.7 cm and 2.9~16.8 cm long in body-length respectively were examined as the material of this investigation. All specimens submitted for the present study were secured monthly from Tokyo Bay by bottom seine with meshes about 0.8 cm from knot to knot in cod-end.

All treatments were made on specimens preserved in about 10% formalin. Body-length was measured, as shown in the Fig. 1, from base of the rostrum to

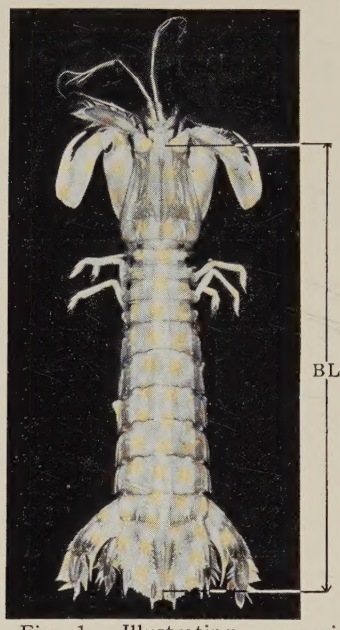

Fig. 1. Illustrating measuring method of body-length (BL) on a specimen of *Squilla oratoria* De HAAN, male, 15.9 cm. in BL.

anterior edge of the median notch of the telson by a rule with one millimeter scale. Body-weight was measured by a balance with a scale readable to 0.2 gram.

Remarkable changes of body-length and body-weight due to preservation are not found to exist as mentioned with regard to these respects in the section (4).

Sex recognition of each specimen treated is based on the external character of the mantis-shrimp. In male, a long tube-like process is found on the inner base of the last each thoracic leg. But it is absent in female. This character is available for this purpose in even such small specimens as about 3 cm long in body-length.

2. Size-difference by fishing ground

To know the localization of the body-size of the animal by fishing grounds, an examination was made using a bottom seine in five different grounds (GI~GV) in the middle part

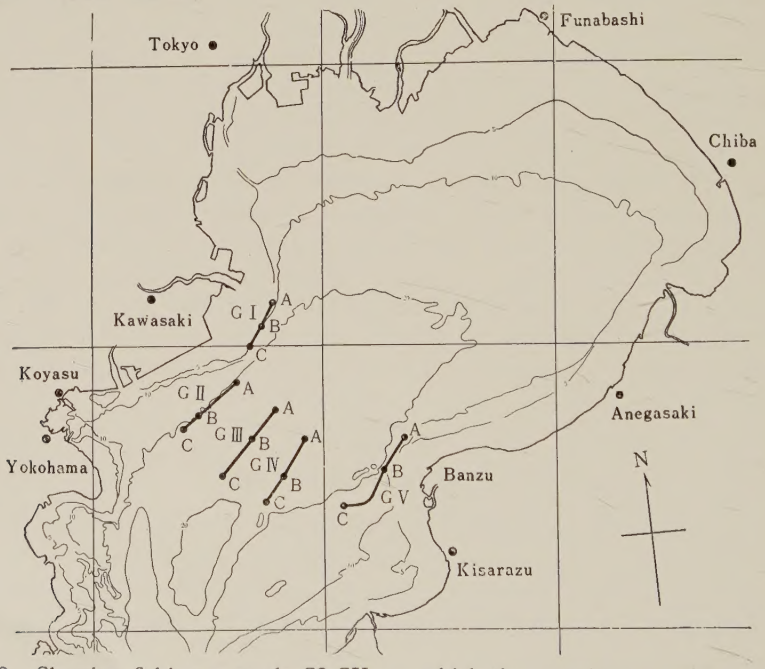

Fig. 2. Showing fishing grounds GI-GV, on which the experiments were done to know the localization of the body-size of the mantis-shrimp. A, B, C, Stations on which observations were made on the depths, water-temperature, bottom characters, and others.

of Tokyo Bay (Fig. 2) on November 24 and 25 of 1955. The seine was operated by fishermen. The depths, water-temperature, bottom substances were inspected in 3 stations (A~C) of each ground, on which the inspection is carried out.

Table 1. Number of the mantis-shrimp catched, mean body-length (B. L.), and the number of the shrimp catched per hour * on each ground.

Sex	Ground	No. of shrimp catched	Mean B. L.	Hours operated	No. c/h*
♀	I	114	9.7	1	114
	II	22	9.2	1	22
	III	7	9.9	1.5	4.7
	IV	14	14.0	2	7
	V	76	11.7	2.83	26.9
♂	I	116	9.9	1	116
	II	22	10.3	1	22
	III	6	7.8	1.5	4
	IV	1	16.2	2	0.5
	V	62	11.4	2.8	21.9

Table 2. Depth, bottom water temperature, hour and distance operated and others.

Ground	St.	Depths (m)	Bottom water temp. (°C)	Hours operated	Distances operated (km)	Wind direction	Wind force
I	A	14.2	16.2	1	2	NNW	1
	B	16.0	16.5			NNE	
	C	14.4	16.6			〃	
II	A	12.0	15.2	1	2.8	NNE	1.5
	B	16.0	16.2			〃	
	C	12.9	16.2			〃	
III	A	30.3	17.2	1.5	3.6	NE	1
	B	27.5	17.3			〃	
	C	29.2	17.3			〃	
IV	A	26.0	17.5	2	3.8		
	B	24.1	17.0				
	C	24.4	17.6				
V	A	19.5	16.5	2.83	5.7	ENE	1.2
	B	19.7	17.2			〃	
	C	19.5	17.5			〃	

The results are given in the Table 1. In total, 440 individuals of the mantis-shrimp were taken in this investigation, among which 233 individuals are of female, and 207 ones are of male.

The body-lengths of them run 4.9~16.7 cm in females, 4.9~16.4 cm in males, and the body-weights of them range 1.6~66.9 g in female and 1.1~64.7 g in male. The average body-length of the mantis-shrimp obtained in each ground and number of the animal catched per hour are listed on the Table 1. Moreover

Table 3. Bottom characters on each station.
* Separation was made by using MARUKAWA's sorting apparatus.

Ground	St.	Bottom character	Sand* (%)	Mud* (%)	Color
I	A	Mud	1.43	98.57	Bluish black gray
	B	〃	1.72	98.28	〃
	C	〃	2.25	97.75	〃
II	A	〃	12.45	87.55	Yellowish black gray
	B	〃	1.73	98.27	〃
	C	〃	0.85	99.15	〃
III	A	〃	1.06	98.94	Light yellow black gray
	B	〃	0.44	99.56	〃
	C	〃	1.43	98.57	〃
IV	A	〃	7.90	92.10	〃
	B	〃	14.35	85.65	〃
	C	〃	8.74	91.26	〃
V	A	〃	2.02	97.98	Yellowish black gray
	B	〃	3.46	96.54	〃
	C	〃	23.46	76.54	〃

the body-length compositions of the mantis-shrimp taken from each fishing ground are designated graphically in the Fig. 3.

According to the data given above it may be said, at least in late November, that much more mantis-shrimps inhabit the grounds I, II, and V than the grounds III and IV, and that smaller sized ones live in the grounds I and II, and larger sized ones in the ground V. The same trend is found to exist with regard to population density of the animal, namely the density is highest in the ground I, next in the grounds II and V, and considerably low in the III and IV. In another words, the mantis-shrimp is found more abundantly in both rather shallow east and west sides than in middle deeper area of the bay. But no relation is found between the density and the bottom water temperature (Tables 1 and 2). Finally it should be mentioned herewith that more future researches are needed to give some conclusive words for those matters set forth above.

The bottom characters on each station of each ground are given in the Table 3. As seen in the table, each station has muddy bottom. No speciality is found to exist. All mud samples examined show a range of 6.0~6.1 in pH.

3. Sex-ratio

Monthly sex-ratio was examined basing on the material obtained in each month. The result is summarized in the Table 4 and is shown in graphic form in the Fig. 4. It may be seen from those that the sex-ratio shows a considerable extent of variation throughout whole the year ranging from 38.7 to 112.5, 77.27 on average, the lowest at February and the highest at October. It is in October only that the ratio is larger than 100, and that is always smaller than 100 in all other months. It is worthy of note that the sex-ratio is considerably

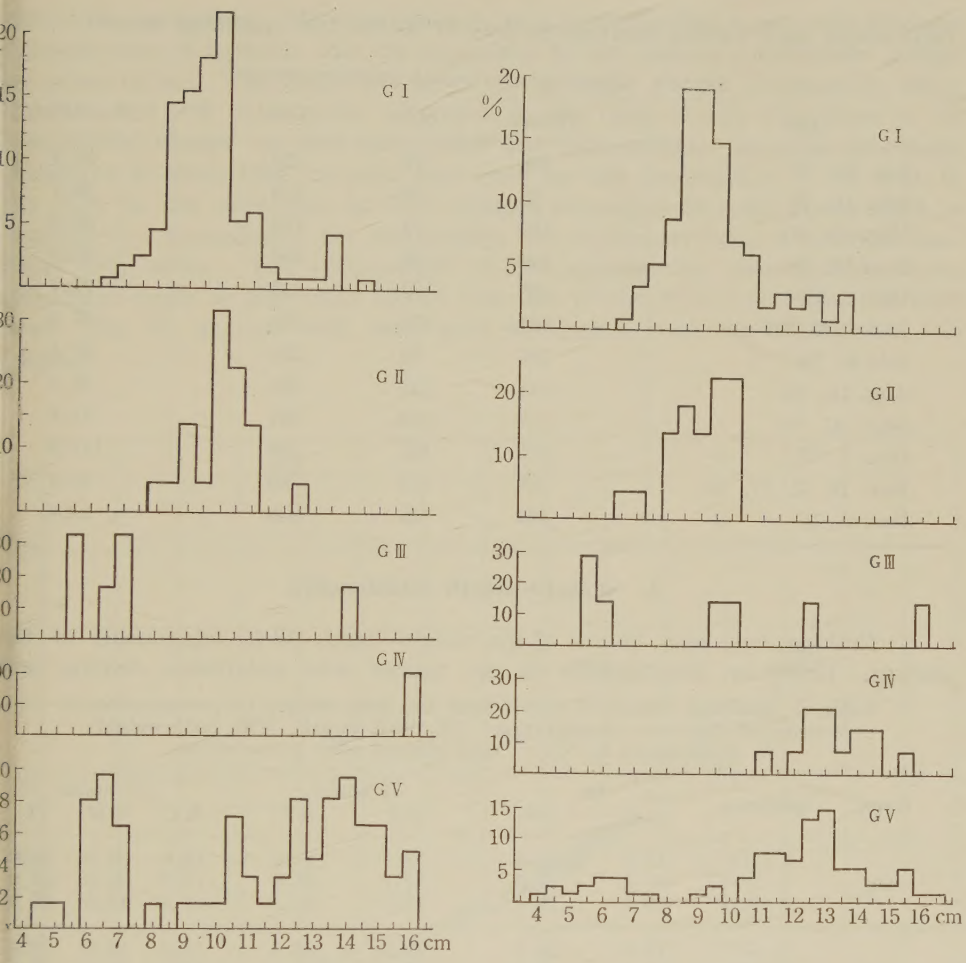

Fig. 3. Body-length composition of female (left) and male (right) of different fishing rounds (GI–GV). Abscissa, body-length of the mantis-shrimp.

maller in such winter months January, February, and March) nan that in other months. But ne reason for this fact is unnown in the present state of ne investigation. Also the ratio apidly increases until the early awning season (June), and sudenly drops in the late spawning eason (July), in which it is 57.1. o far as the present study goes, is difficult to understand the eaning of the matter that the

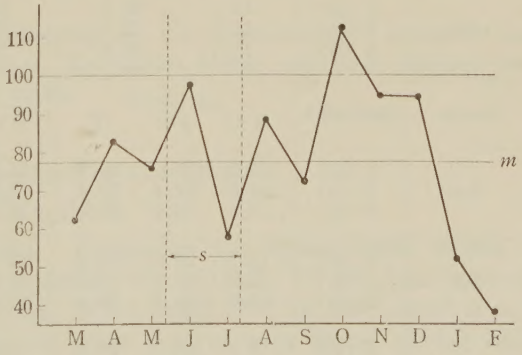

Fig. 4. Monthly change of sex-ratio of the mantis-shrimp during one year. m, mean; s, main spawning season. Abscissa, months.

ratio shows such sudden decrease in July or in the late spawning season.

Table 4. Showing sex-ratio of monthly sample.

Date	Female	Male	Total	Sex-ratio
Jan. 14, '56	146	76	222	52.1
Feb. 11, '56	93	36	129	38.7
Mar. 10, '56	119	74	193	62.2
Apr. 12, '56	106	88	194	83.0
May 9, '56	235	178	413	75.7
June 7, 8, '56	181	177	358	97.8
July 9, '55	147	84	231	57.1
Aug. 10, '55	171	151	322	88.3
Sept. 10, '55	142	102	244	71.8
Oct. 8, '55	112	126	238	112.5
Nov. 10, 11, 17, '55	185	174	359	94.1
Dec. 9, '55	134	126	260	94.0

4. Weight-length relationship

Nothing has been known of the weight-length (W-L) relationship of this shrimp. Hence an investigation of the matter was undertaken dealing with

Table 5. Showing change of body-length and body-weight by preservation of formalin of different concentration. BL, body-length; BW, body-weight; T, temperature in °C; *, time elapsed after preservation.

Items	Specimen	0*		2 hours		17 hours		
		BL	BW	BL	BW	BL	BW	T
5%	1 (♀)	13.5	31.4	13.5	31.3	13.6	31.5	28.0
	2 (♀)	12.0	22.6	12.7	23.4	12.8	23.6	28.0
	3 (♂)	10.9	19.4	11.9	18.7	11.5	18.5	28.0
7%	1 (♀)	12.2	24.1	12.5	24.0	12.2	23.9	28.0
	2 (♂)	12.1	23.6	12.7	24.5	12.5	24.0	28.0
	3 (♂)	12.5	25.8	13.1	25.6	12.5	24.5	28.0
10%	1 (♀)	11.1	18.2	11.4	18.8	11.6	19.0	28.2
	2 (♂)	11.7	22.3	12.4	23.8	12.1	23.3	28.2
	3 (♂)	12.4	26.8	12.6	26.8	12.6	26.8	28.2

Items	Specimen	24 hours			135 hours			102 days & 20 h.		
		BL	BW	T	BL	BW	T	BL	BW	T
5%	1 (♀)	13.7	32.0	29.4	13.7	32.5	28.5	13.6	31.9	14.3
	2 (♀)	12.6	24.4	29.4	12.8	24.8	28.5	12.6	24.1	14.3
	3 (♂)	11.6	18.6	29.4	11.4	18.2	28.5	11.3	17.6	14.3
7%	1 (♀)	12.3	24.0	29.2	12.3	23.6	28.5	12.1	31.1	14.5
	2 (♂)	12.5	24.6	29.2	12.5	24.7	28.5	12.3	24.0	14.5
	3 (♂)	12.5	24.8	29.2	12.6	24.5	28.5	12.3	24.4	14.5
10%	1 (♀)	11.6	18.8	29.3	11.6	18.7	28.5	11.4	17.9	14.5
	2 (♂)	12.3	23.9	29.3	12.3	23.3	28.5	12.1	23.0	14.5
	3 (♂)	12.6	27.2	29.3	12.8	27.4	28.5	12.4	26.2	14.5

numerous specimens. It was guessed by an examination made with different concentration of formalin that the specimens do not undergo considerable change by preservation. The Table 5 is given as the result of the examination using 5%, 7%, and 10% of formalin. A glance at this table reveals that there is no remarkable change on both body-length and body-weight. Since the specimens preserved in about 10% formalin were used for this investigation. As seen in the Fig. 5, the difference of W-L relation between both sexes is too slight to warrant it. Accordingly the relationship was treated on basis of material combined both sexes. The body-weight of the soft-shrimps after ecdysis shows sometimes more or less lower values than that of the normal shrimps with hard shell (Fig. 5), so that soft ones were eliminated from the treatment of this respect.

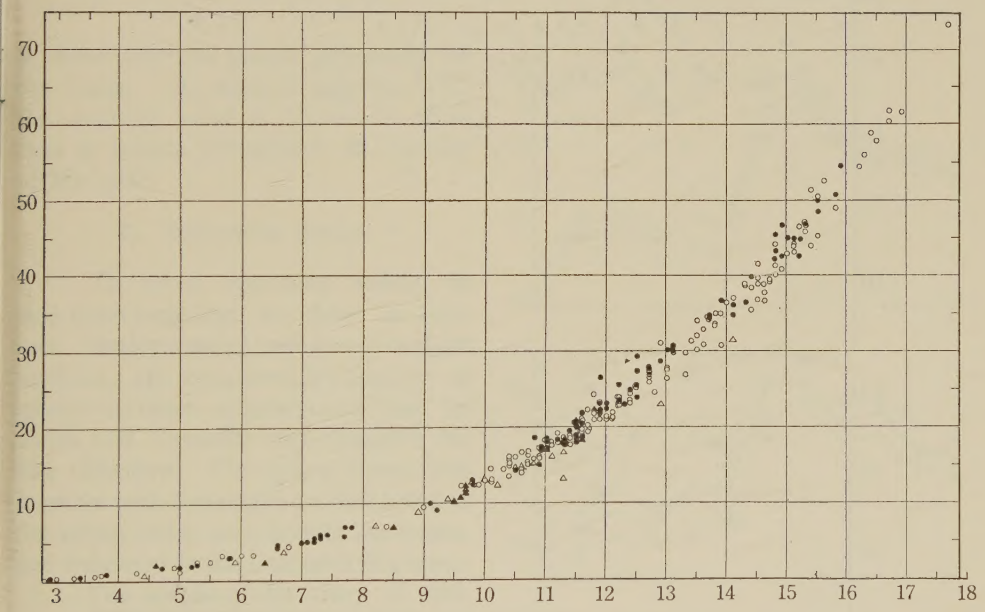

Fig. 5. Showing weight-length relationship of the mantis-shrimp. Ordinate, body-weight in gram; abscissa, body-length in cm. Soft circles, female; solid ones, male; soft triangles, soft females; solid triangles, soft males.

The relationship may be expressed by the formula,

$$W = aL^b$$

where a and b represent constants. Computing the approximate values, we have $W = 0.02313L^{2.8131}$ for January material, $W = 0.01141L^{3.0716}$ for April material, $W = 0.01908L^{2.8420}$ for July material, and $W = 0.01462L^{2.9646}$ for November one. It is worth noting herewith that the constant b is, as seen above, having values approximate to 3. Thus the cube law may be applied too in this animal as is the case with most fishes.

5. Ponderal index

The index (PI) were obtained by the following formula,

$$PI = W/L^3 \times 10^3 ,$$

where L presents body-length and W shows body-weight. PI of the shrimp is subject to a considerable variation, but it shows no gradual change in relation to body-length at least within the limit from 9 cm to 17 cm in body-length as shown in the Fig. 6 A and B. While that of the soft shrimp sometimes gets much smaller values in comparison with that of the normal one (Fig. 6, A and B).

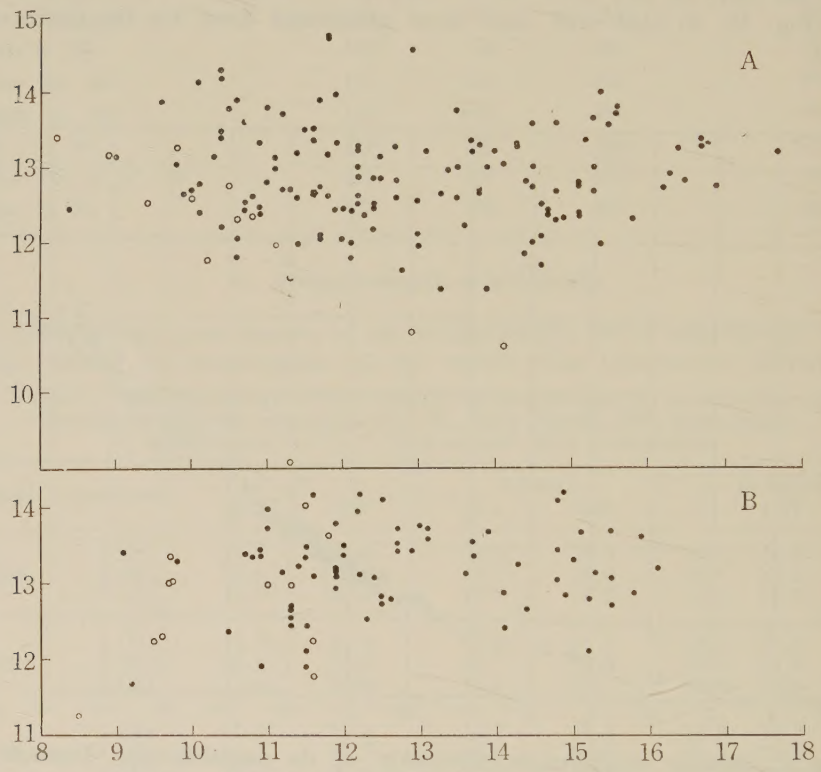

Fig. 6. Showing ponderal index (PI) (Ordinate) in relation to body-length (Abscissa) in cm basing on 147 females including 14 soft-shrimps in Fig. A, on 84 males including 12 soft ones in Fig. B.

Monthly change of the index was examined with regard to specimens larger than 11 cm in body-length in order to know the seasonal fluctuation. The result is given in the Table 6 and Fig. 7, A~C. The average value of the index is the lowest in June, and heighest in December and January, and gradually decreasing towards June. Moreover the average value is considerably larger in late winter and early spring than in late summer and early autumn. Such tendency given above is seen irrespective of sex. The value is 12.28 and 12.88 in June and is 14.46 and 15.08 in December in female and male respectively. Finally attention

Table 6. Monthly average ponderal index (PI) and its confidence interval (CI) of the mantis-shrimp. NI, number of individual used for this examination.

Month	Female		Male	
	NI	PI and CI	NI	PI and CI
June	21	12.28 ± 0.36	26	12.88 ± 0.31
July	52	12.94 ± 0.16	23	13.18 ± 0.22
Aug.	37	13.07 ± 0.24	20	13.43 ± 0.33
Sep.	50	12.70 ± 0.21	43	13.23 ± 0.20
Oct.	15	13.02 ± 0.41	11	13.74 ± 0.67
Nov.	37	12.91 ± 0.31	36	13.69 ± 0.35
Dec.	17	14.46 ± 0.37	26	15.08 ± 0.40
Jan.	73	14.80 ± 0.21	34	15.12 ± 0.28
Feb.	87	13.91 ± 0.18	32	14.57 ± 0.24
Mar.	67	13.86 ± 0.17	26	14.70 ± 0.33
Apr.	54	13.74 ± 0.19	21	14.22 ± 0.33
May	65	13.60 ± 0.16	40	14.07 ± 0.24

is called here to sexual difference of the index. As seen in the Fig. 7, C, the average value is larger in male than in female throughout all months of the year.

6. Spawning season

To know spawning season of this mantis-shrimp, we chose an indirect method using an ovary-weight analysis. A considerable number of specimens taken monthly and fixed by about 10% formalin were available for this objective. The ovary dissect out together with both right and left lobes of the organ from each female specimen, and weighted to the nearest 0.05 grams.

The weight of the ovary of each specimen dealt with is plotted on the Figs. 8 and 9 in relation to the body-length. In other hand, average values of the weight were calculated on three classes of the body-length assorted as 10~12 cm, 12~14 cm, and 14~16 cm. The females under 10 cm in body-length are omitted from this treatment because of such females appear to be not concerned yet to the spawning as the ovaries of such females are always in immature state. The females which are over 16 cm in body-length are also

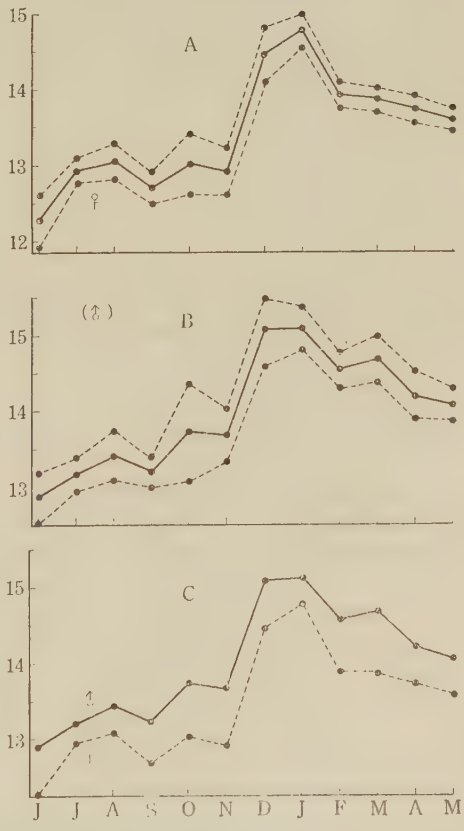

Fig. 7. Showing monthly average ponderal index. Abscissa, months. Broken lines in A and B, showing confidence interval.

omitted from the treatment as they are scarce in number. The result of this calculation is given in the Fig. 10. From those, at least, the following two

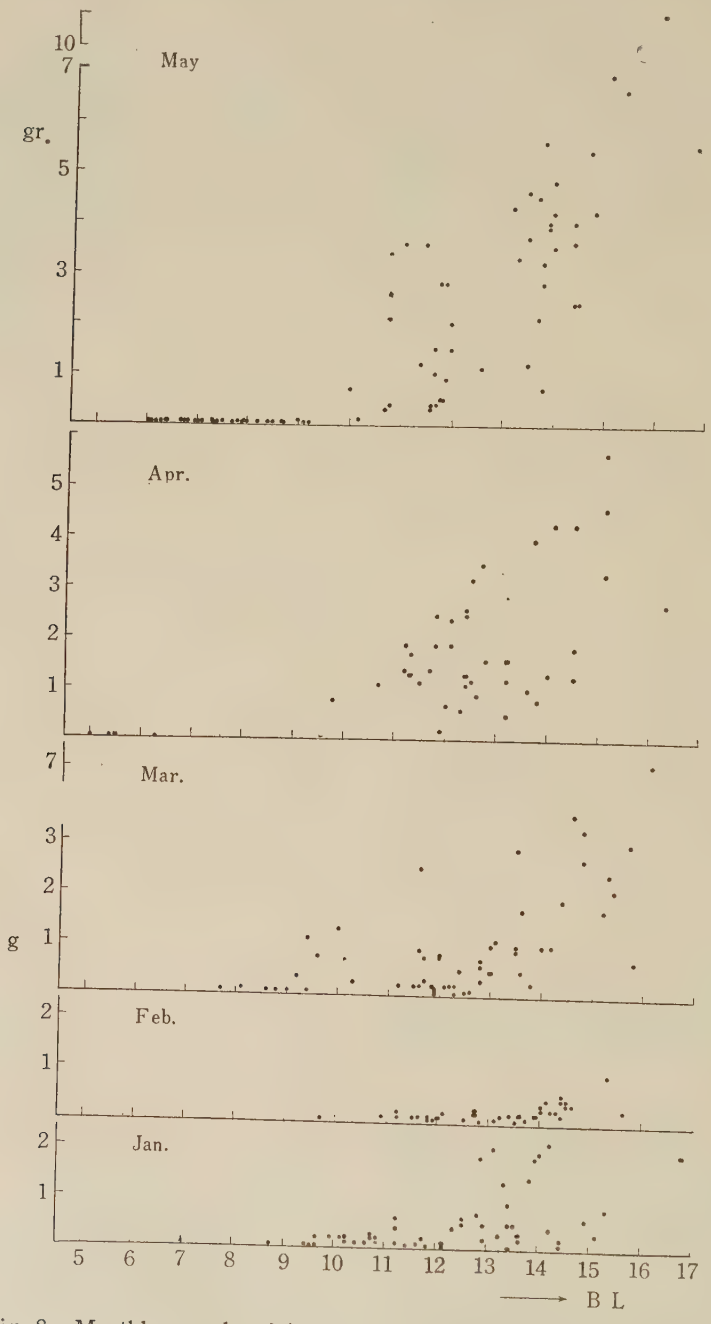

Fig. 8. Monthly gonad weight (ordinate) in gram in relation to body-length (abscissa) in cm.

matters are found to exist, namely, (1) there is a remarkable seasonal dynamics of the ovary-weight, and (2) a positive relation between body-length and the weight of the organ may be recognized.

With regard to the first, we may be said as follows: the ovary weight of the females larger than about 10 cm in body-length becomes increase starting from about March, and it seems to show the maximum augment in May in the females measuring 12 ~14 cm in body-length as seen in the Fig. 10, B, and in June in females 14~16 cm long as shown in the Fig. 10, C. In the 14~16 cm-group, the increase of the gonad appears to commence as early as March, and it continues gradually for April and May, and the maximum occurs in June as set forth already. But it becomes somewhat decreasing in July, and more diminishing is found in August as seen in the Fig. 10, C. But in the 10 ~12 cm-group, it seems that there is no remarkable seasonal change of this item in question present as seen in the Fig. 10, A.

For the second, some lines will be given below. Of this item, at least, two facts (a) and (b) are recognizable.

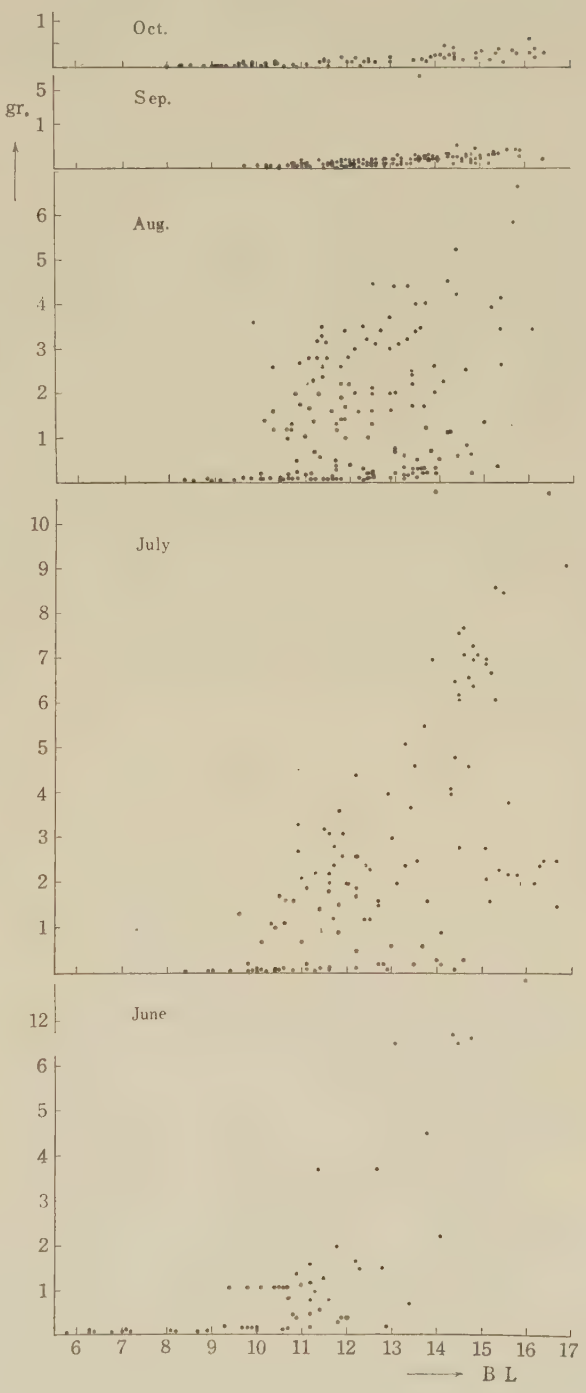

Fig. 9. The same as is the case with the Fig. 8.

Table 7. Average ovary-weight in gr assorted by month and body length (BL). Figures given in parentheses are showing number of individuals examined.

Date \ BL	10–12 (cm)		12–14 (cm)		14–16 (cm)	
Jan. 14	0.46	(16)	0.61	(23)	0.84	(9)
Feb. 11	0.10	(8)	0.15	(17)	0.59	(14)
Mar. 10	0.46	(14)	0.68	(22)	2.54	(12)
Apr. 12	1.12	(13)	1.49	(21)	3.32	(9)
May 9	1.48	(20)	3.10	(16)	4.36	(11)
June 7	0.61	(17)	2.41	(7)	5.40	(4)
July 9	1.40	(46)	2.23	(32)	4.66	(34)
Aug. 10	1.17	(68)	1.45	(69)	2.57	(20)

(a) the relationship between the ovary-weight and body-length seems to be an exponential as being the gonad weight increases gradually from about 10 cm to 15 cm in body-length and it makes considerably sudden augment in the size larger than 15 cm in body-length. The Figs. 8 (May) and 9 (June) are referred for this matter. The largest ovary-weight is observed in a specimen 16 cm long taken in June 7, in which it weights 12.8 g.

(b) two groups may be recognized of the ovary-weight in the females having body-length larger than about 11 cm. In one group, the gonad weight is considerably larger than that of the other group although the body-size is the same. In the other group, the weight is conversely smaller than that of the other one. Such picture is rather conspicuously shown in the figures plotted the gonad-weight of the April- and July-specimens (Figs. 8, April and 9, July). However the biological meaning of the fact does not hully discussed within the scope of the present investigation.

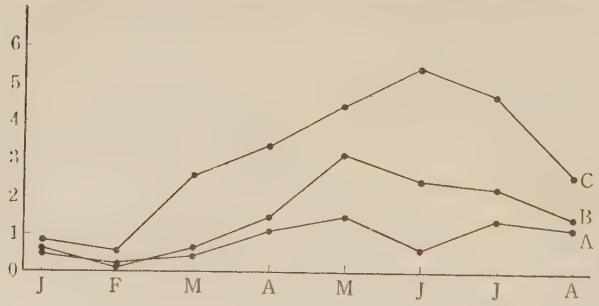

Fig. 10. Monthly average ovary weight in gram in three size groups (A, B, C). Ordinate, ovary weight together with both right and left lobes of ovary; abscissa, months. A, group-A, 10–12 cm in body-length; B, group-B, 12–14 cm in body-length; C, group-C, 14–16 cm in body-length.

Finally the following may be summarized as a result of the ovary-weight analysis basing on the material secured monthly through a year. The spawning season appears to run for a period from the middle of May to early of July, and the spawning seems to be at its height in June, at least, in the Tokyo Bay. This conclusion compretly agrees with the description given by KOMAI (1924, p. 274). His description is as follows:—"Such (mantis) shrimp (keeping the egg-cluster on her mouth) begin to appear in that bay usually in the middle of May, and increase in number toward the end of the same month and are fairly abundant in

June. They become rarer at the beginning of July and they are usually no longer found at the end of the same month, although, according to some of the fishermen of the village, mantis-shrimps carrying eggs may be caught from time to time in August."

7. Mass-growth

Inasmuch as there is no direct method to know the growth of this shrimp, an indirect method was employed, viz., a consecutive collection was made, and an analysis of the body-length frequency distribution was carried out on basis of a series of the material taken monthly by fishermen. To analyse the frequency distribution of the body-length, the method which was developed by HARDING (1949) was employed. By using the method, it is possible to separate each group or population included within a material of a certain month, if each group of it

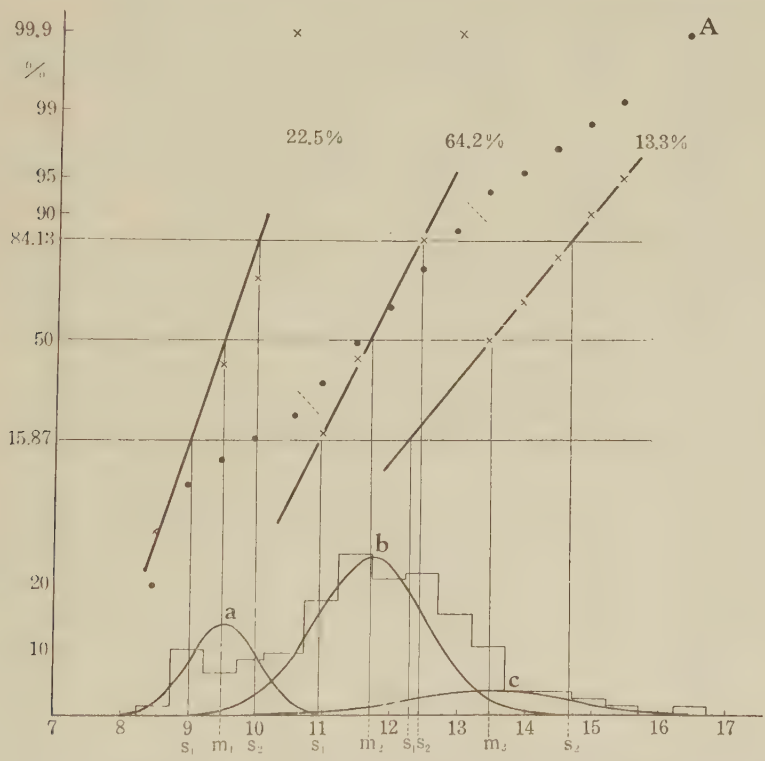

Fig. 11. Recognition of group analysis by using Harding method on the male material taken on August 10, 1955, including 151 individuals. m_1, m_2, and m_3, means of the group-a, -b and -c respectively. S_1 and S_2 see text.

is in normal distribution in its size frequency. When all the data are plotted on probability graph paper as cumulative percentages, a curve is given (Fig. 11, A). This curve is the resultant of two or more straight lines. Each straight line of

Table 8. Mean values ($\overline{m}$) and others of the body-length of each group found on female material taken monthly. Dimensions in cm. S_1 and S_2, see text. Marks a–d correspond to those of the Figs. 12 and 13.

Months	Groups	Total number	No. individuals of each group (%)	S_1	S_2	σ	$\overline{m}$ (cm)	Marks
Jan.	1st	146	9 (6.1)	6.7	8.5	0.91	7.6	b
	2nd		63 (43.1)	9.1	10.3	0.59	9.7	b
	3rd		66 (45.0)	10.9	13.0	1.04	12.0	c
	4th		8 (5.4)					
Feb.	1st	93	6 (6.4)	8.9	10.3	0.69	9.6	b
	2nd		43 (46.2)	10.9	12.4	0.73	11.6	c
	3rd		44 (47.3)	12.7	14.4	0.84	13.5	c
Mar.	1st	119	14 (11.7)	5.3	8.4	1.65	6.8	a
	2nd		37 (31.0)	7.5	9.6	1.05	8.5	b
	3rd		56 (47.0)	10.9	13.1	1.06	12.0	c
	4th		12 (10.0)	14.3	16.3	0.90	14.8	d
Apr.	1st	106	20 (18.8)	4.1	5.9	0.93	5.0	a
	2nd		17 (16.0)	5.9	7.5	0.80	6.7	a
	3rd		60 (55.6)	10.1	12.4	1.11	11.3	b
	4th		9 (9.4)	13.9	14.8	0.48	14.4	c
May	1st	235	97 (41.2)	5.5	6.8	0.71	6.1	a
	2nd		99 (42.1)	6.9	10.7	1.87	8.8	b
	3rd		38 (16.1)	13.1	15.1	0.94	14.1	c
	4th		1 (0.0)					
June	1st	181	73 (40.3)	6.1	8.2	1.07	7.1	a
	2nd		80 (44.2)	9.0	10.4	0.73	9.7	b
	3rd		17 (9.3)	10.9	12.3	0.72	11.6	c
	4th		7 (3.8)	13.4	14.4	0.49	13.9	c
	5th		4 (2.2)					
July	1st	147	9 (6.1)	7.8	9.8	1.01	8.8	b
	2nd		85 (57.8)	10.1	12.0	0.98	11.1	c
	3rd		53 (36.1)	13.3	15.4	1.08	14.3	d
Aug.	1st	171	9 (5.3)	8.0	9.1	0.50	8.6	b
	2nd		85 (49.7)	10.1	11.6	0.76	10.8	c
	3rd		68 (39.8)	12.3	13.5	0.64	12.9	c
	4th		9 (5.3)	14.2	15.2	0.52	14.7	d
Sep.	1st	142	85 (59.9)	10.4	12.4	0.99	11.4	c
	2nd		57 (40.1)	13.1	14.7	1.16	13.9	d
Oct.	1st	112	14 (12.5)	7.8	8.5	0.35	8.2	b
	2nd		47 (42.0)	9.8	11.3	0.73	10.5	b
	3rd		47 (42.0)	11.5	13.1	0.81	12.2	c
	4th		4 (3.5)					
Nov.	1st	185	70 (37.8)	7.3	9.0	0.85	8.1	b
	2nd		97 (52.4)	10.4	13.5	1.52	12.0	c
	3rd		16 (8.6)	14.4	15.6	0.60	15.0	d
	4th		2 (1.0)					
Dec.	1st	134	17 (12.7)	5.9	7.3	0.70	6.6	a
	2nd		97 (72.4)	7.3	9.1	0.86	8.2	b
	3rd		10 (7.5)	10.7	12.2	0.77	11.5	c
	4th		10 (7.5)	11.2	14.1	1.48	12.7	c

Table 9. Mean values ($\overline{m}$) and others of the body-length of each group found on male material obtained from month to month. Dimension in cm. S_1 and S_2, see text.

Months	Groups	Total number	No. individuals of each groups (%)	S_1	S_2	σ	$\overline{m}$
Jan.	1st	76	8 (10.5)	6.7	8.2	0.73	7.5
	2nd		34 (44.7)	9.1	10.1	0.52	9.6
	3rd		19 (25.0)	10.3	11.9	0.80	11.1
	4th		15 (19.7)	12.1	13.1	0.92	13.1
Feb.	1st	36	5 (13.8)	9.3	11.2	0.94	10.2
	2nd		18 (50.0)	10.9	12.8	0.91	11.9
	3rd		12 (33.3)	12.7	13.7	0.52	13.2
	4th		1 (2.7)				
Mar.	1st	74	6 (8.1)	4.9	6.7	0.90	5.8
	2nd		32 (43.2)	7.4	8.7	0.67	8.1
	3rd		14 (18.9)	9.2	10.8	0.77	10.1
	4th		20 (27.0)	11.1	13.5	1.17	12.3
	5th		2 (2.7)				
Apr.	1st	88	41 (46.5)	4.7	6.7	0.99	5.7
	2nd		38 (43.1)	8.6	11.2	1.28	10.0
	3rd		9 (10.2)	12.6	14.1	0.73	13.3
May	1st	178	101 (56.7)	5.3	7.3	0.97	6.3
	2nd		48 (26.9)	7.2	11.3	2.03	9.2
	3rd		29 (16.2)	13.0	15.2	1.01	14.0
June	1st	177	86 (48.5)	5.8	7.9	1.06	6.8
	2nd		81 (45.7)	8.1	11.3	1.58	9.7
	3rd		10 (5.6)	12.3	14.9	1.30	13.7
July	1st	84	11 (13.1)	8.7	10.1	0.69	9.4
	2nd		50 (59.5)	10.5	12.1	0.80	11.3
	3rd		23 (27.4)	13.4	15.2	0.86	14.3
Aug.	1st	151	34 (22.5)	9.0	10.0	0.48	9.5
	2nd		97 (64.2)	10.8	12.4	0.81	11.7
	3rd		20 (13.3)	12.3	14.7	1.20	13.5
Sep.	1st	102	20 (19.6)	10.2	12.1	0.97	11.1
	2nd		80 (78.4)	12.4	14.0	0.83	13.2
	3rd		2 (1.9)				
Oct.	1st	126	39 (31.0)	7.8	8.9	0.53	8.6
	2nd		68 (54.0)	10.7	12.3	0.83	11.5
	3rd		19 (15.1)	12.3	14.3	0.98	13.3
Nov.	1st	174	110 (63.2)	7.5	9.3	0.93	8.4
	2nd		19 (10.9)	10.0	11.6	0.74	10.8
	3rd		45 (25.7)	25.7	14.8	0.94	13.9
Dec.	1st	126	106 (84.1)	7.0	9.7	1.31	8.4
	2nd		12 (9.5)	10.9	12.4	0.77	11.7
	3rd		8 (6.3)				

this curve represents a group which belongs to a normal distribution. Thus we can be able to know the number of groups included within a material of a certain month. Then the mean body-length and the standard deviation of each-group is obtainable graphically. The mean value (m) of the body-length of each

normally distributed group is the length corresponding to the point which stands on the cross point (M) of the straight line in question and the line passing on the points for 50% of the probability graph paper. The standard deviation (σ) is obtained by the formula, $\sigma=(S_1-S_2)/2$, where S_1 is the length corresponding to

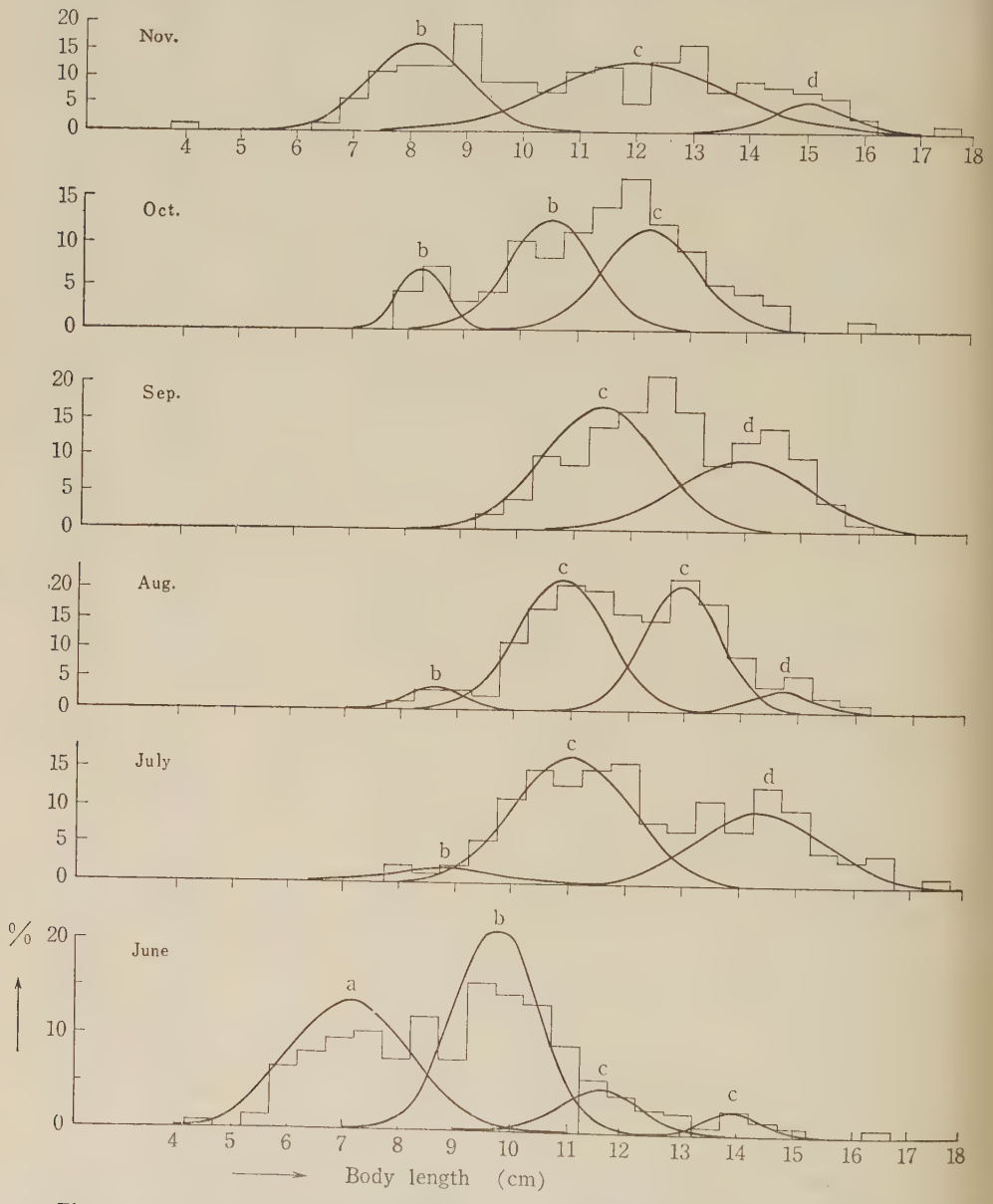

Fig. 12. Monthly body-length distribution (from June to November). Groups (a–d) of each month separated by using Harding method. Ordinate, number of individuals; abscissa, body-length in cm.

the point which lies on the cross point of the straight line and the line running on the points for 15.87% of the probability graph paper, and S_2 is samely the length corresponding to the point that stands on the janction point of the straight line and the line passing through the points for 84.13% of the graph paper.

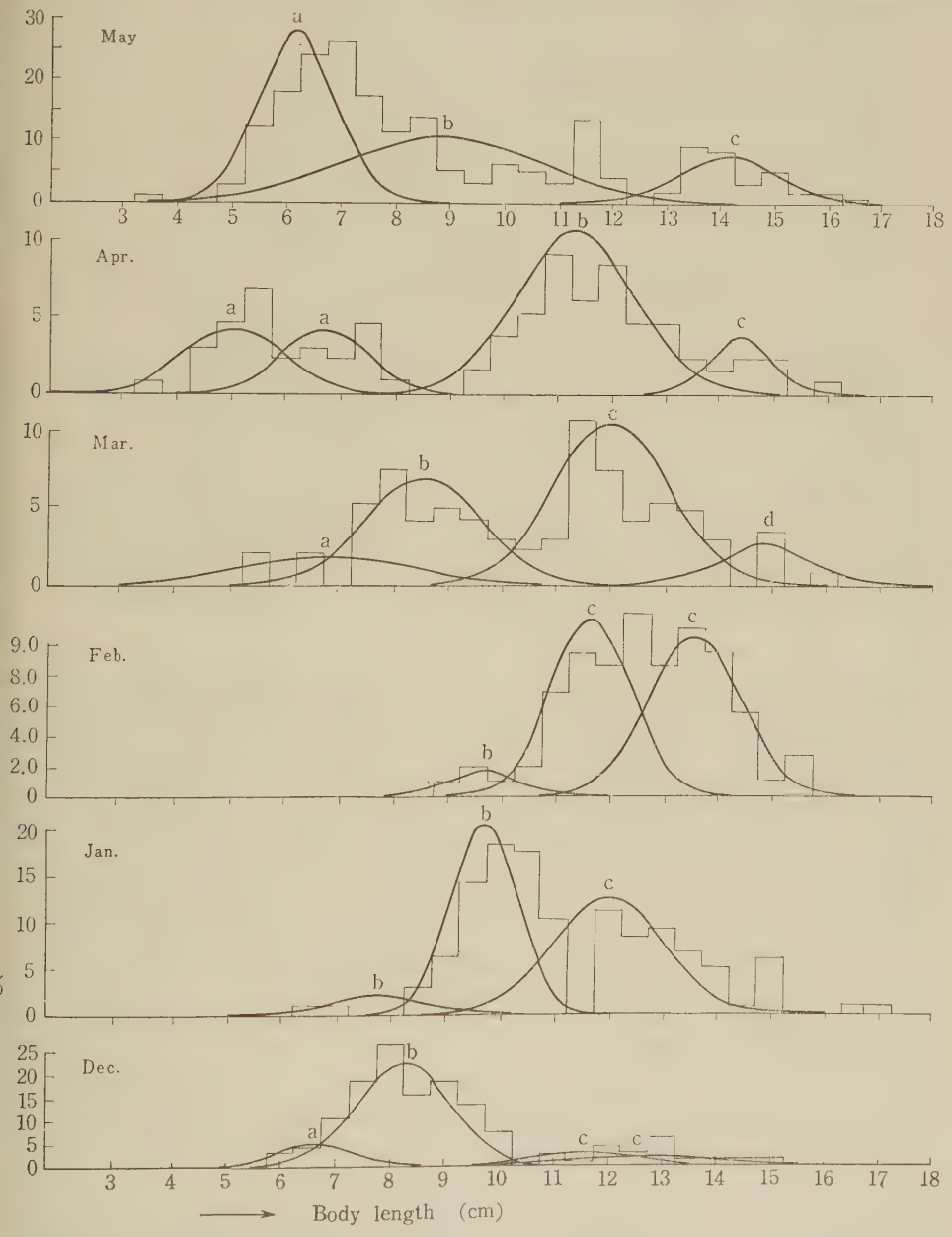

Fig. 13. Monthly body-length distribution (from December to May). Others are the same as is the case with the Fig. 12.

In the present investigation, the values of m、and σ taken from graphic method was checked by those obtained by calculation, and we found that there is little discrepancies are present between them. However, m and σ, those are gained by mathematical method, are used for the calculation of the theoretical frequencies of normal curves of each group.

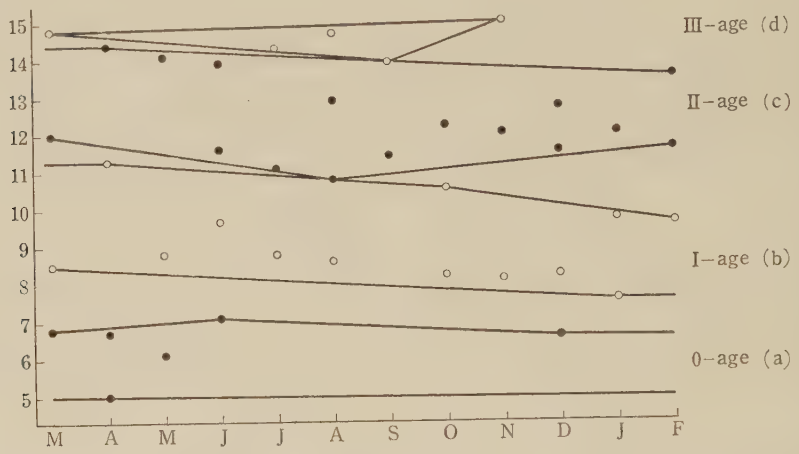

Fig. 14. Mean values of body-length of male of each group found on each month. To make recognition easy, the groups of O-age and II-age, and those of I-age and III-age are represented by black and white circles respectively. Ordinate, body-length in cm; abscissa, months. a, b, c and d correspond to those of the Figs. 12 and 13.

The body-length frequency distributions of the shrimp consecutively taken are considerably complex as given in the Figs. 12 and 13. But the mass-growth could be seen by plotting the mean values of each group found on the monthly material as shown in the Fig. 15. The mean values on which the Fig. 15 is based are listed on the Tables 8 and 9 and, plotted on the Fig. 14. From the Fig. 15 the following may be said. There is no sexual difference in growth rate, but in life-span, which appears to be somewhat longer in female than in male. The longevity is, at least, seems to be about 3 years and 9 months in female and 3 years and 5 months in the other after hatching. This agrees well with the Petersen curve of the body-length of the mantis-shrimp taken in June. In the June-material, four groups, a, b, c, and c (Fig. 12) in female, and three ones (Table 9) in male are presnt. Of those, a, b, and c of both sexes appear to belong to 0-, I-, and II-age groups respectively (Fig. 15). The two groups within the C-group of female seem to the present authors to be merely subgroups of the group C. As June corresponds to the main spawning season, it follows therefore that the agreement of those facts given above means that the determination of the longevity is largely reasonable.

The mean body-lengths of each age-group are, within the limit of the present material, ranging 5.0～7.2 cm, 7.5～11.3 cm, and 9.4～14.4 cm in 0-, I-, and II-age groups respectively irrespective of sex. The largest average body-

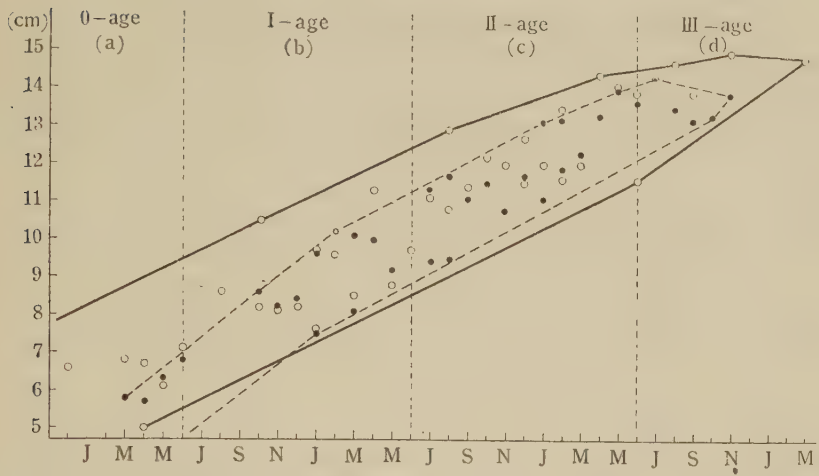

Fig. 15. Showing the mass-growth of the *Squilla oratoria* based on the average body-length of each group found on the material taken monthly. Vertical broken lines show main spawning season. White, female; Black, male. a, b, c and d, correspond to those of the Figs. 12, 13 and 14.

length of the III-age group is 15.06 cm in female, 14.35 cm in male (Tables 8, 9 and Fig. 15). While the largest one in individual among all specimens submited for this study is 17.7 cm and 16.8 cm in female and male respectively.

8. Feeding habit

As given in the Table 10, 190 females and 221 males, in total 411 specimens, ranging 4.5~16.8 cm in body-length, were examined for the analysis of stomach content. The specimens were caught during the time 10 a.m.~3 p.m., and preserved with ca. 10% formalin in laboratory after carrying them from the fishing ground. Then each specimen is dissected for the purpose said above. Some mentions on the result taken from the examination would be given below.

Nearly all important food elements found on the stomach contents of the mantis-shrimp taken monthly except July, October, and December are given in the Table 11. As seen from the table, the food composition is rather complex as it consists of many kinds of animals, algae, and diatoms. Animal foods are mostly composed of crustacea, pisces, mollusca, and annelida. Frequencies of occurrence of those animals of each month, and those in total are put on the Table 12. From the table, it reveals that crustacea and pisces usually show much higher percentages, especially the former, in comparison to mollusca and annelida, though all of them are subject to considerable variation by month. In January, pisces are larger than crustacea in frequency percentage as being 26.8% for crustacea, and 34.1% in pisces. The percentage of mollusca a little less than that of annelida, which is 9.8% and 12.2% respectively. Details of concrete food elements found on the stomach contents of the January-material are set forth in the Table 11. In the February-material, it is remarkable that pisces occur few

Table 10. Number of specimens examined for stomach content analysis. *, on which the specimens were collected.

Date*	♀	♂	Total
Jan. 14	20	21	41
Feb. 11	16	9	25
Mar. 10	26	12	38
Apr. 11	19	20	39
May 9	46	35	81
June 7, 8	40	31	71
Aug. 10	—	30	30
Sep. 10	—	52	52
Nov. 10, 11	23	11	34
Total	190	221	411

and *Crangon affinis* (=*Crago affinis*), the most abundant bottom shrimp in Tokyo Bay, appears much. The percentages are 16% and 60% in the former and the latter respectively. The occurrence of mollusca is also larger than that of the January-material, but that of annelida is similar to that of the January one. In the March material, crustacea are found much continuously. Pisces appear in remarkably high percentage, next to that of the August material, as being 47.4%. Mollusca and annelida are found in less percentage. In the April-material, crustacea are also in high percentage, 53.8%, and pisces are of 28.2%. No annelida is found to eat. In May an inactivity in feeding is found to exist as mentioned later. Crustacea and pisces are of 35.8% and 3.7% in occurrence respectively. Both mollusca and annelida are the same in occurrence, merely 1.2%. In the June material, crustacea are found again in high percentage as same as that seen in the case of the specimens taken in February, March, and April. Among the crustacea detected in the stomach contents, such srhimps as *Crangon affinis* and *Alpheus japonicus* were found in high occurrence. In the August material, crustacea are scarce, only 20%. On the contrary the percentage of pisces is the highest, 56.7% throughout the months, on which this analysis is concerned. But mollusca and annelida, both of them are the same in frequency of occurrence, show rather high percentage. A number of scales similar to those of *Acanthogobius flavimanus* and many white and thin shell-fragments were found. It has not been easy to identify the shell-fragments. Nevertheless those appear to be the mix of shell-fragments of *Philine japonica* Lischke and *Raeta yokohamaensis* judging from general aspects of them. For September material, it may be said that crustacea, pisces, and mollusca are rather even in occurrence as they found in 46.2%, 44.2%, and 38.5% respectively, and annelida are considerably less, 19.2%, than those. In this case, such decapod crustacea as *Metapenaeopis dalei* (?), *Trachypenaeus curvirostris*, *Crangon affinis*, and *Pilumnoplax vestita* are found as the stomach contents. Later three of which are common species with considerable abundance in Tokyo Bay. Of the white shell-fragments, some ones appear to belong to the shell of *Philine japonica* Lischke and other some ones may be referred to that of *Raeta yokohamaensis*. In the November material, *Crangon*

Table 11. Food elements found in the stomach contents of *S. oratoria*.

January	Body-parts (legs, fragments of carapace, rostrum, etc.) of crabs and shrimps; fish scales (cycloid and ctenoid) and scales of *Engraulis japonica* (?); shell fragments of *Detalium* sp; body-parts af sand worms (*Nereis* and others); bristles of sand worms; semidigested fish and squid meats; mud.
February	Body-parts and eggs of *Crangon affinis*; body-parts of shrimps and crabs; fish scales (cycloid and ctenoid) and fish bones; body-parts of *Nereis*; polychaete bristles; body-parts of young octopus; diatoms; fragments of alga; mud.
March	Body-parts and eggs of shrimps (mostly *Crangon affinis*) and crabs; fish scales (cycloid and ctenoid) and fish bones (mostly fin rays); considerably digested fish-body (goby ?); fragments of bivalve shells; body-parts of *Nereis*; polychaete bristles; diatoms; fragments of an alga; mud.
April	Body-parts and eggs of shrimps (mostly *Crangon affinis*) and crabs; cephalothorax of a penaeid; fish scales (cycloid, ctenoid) and fin-rays; young of bivalve and snail; fragments of bivalve shells; somewhat digested animal meat; diatom; fragments of an alga; mud.
May	Body-parts and eggs of shrimps (mostly *Crangon affinis*) and body-parts and chela of *Alpheus japonicus*; fish scales (cycloid and ctenoid); young of snail; body-parts of *Nereis*; somewhat digested animal meat; diatoms; mud.
June	Body-parts (eyes, telson, legs, etc.) of shrimps (mostly *Crangon affinis* and *Alpheus japonicus*); eggs of *C. affinis*; vertebral bones of fish; otoliths and fin-rays; youngs of bivalves and snails; bristles of polychaeta; somewhat or half digested animal meat; mud.
August	Fragments of *Pilumnoplax vestita*; eye and gills of crab; chela of *Crangon affinis*; fish bones, scales (some ones of them resemble those of *Acanthogobius flavimanus* and some species of flat fishes), and otoliths; fragments of white thin shells of a bivalve, *Philine japonica* LISHKE, polybhaete bristles; mud.
September	Body-parts of *Metapenaeopsis dalei* (?), *Trachypenaeus curvirostris*, and *Crangon affinis*; body-parts of crabs and shrimps; carapace fragments of *Pilumnoplax vestita*; body-parts of Amphipoda; fish bones, scales (cycloid, ctenoid), otoliths; shell fragments of *Philine japonica* LISCHKE and other bivalves; Gastropod young; polychaete setae; diatoms; mud.
November	Carapace-fragments of *Pilumnoplax vestita*; body-parts (antennal scale and others) of *Crangon affinis*; body-parts of *Alpheus japonicus* (?); legs and eyes of crabs; thoracic legs of an amphipod; fish scales (cycloid and ctenoid), otoliths, and fin-rays; considerably digested fish meat; shell fragments of bivalves; squid meat (leg); polychaete bristles; diatoms; mud.

nis, *Alpheus japonicus*, and *Pilumnoplax vestita* are detected besides many
-scales, fin-rays, shell-fragments of bivalves, and others. The shell fragments
referable to the shell of *Raeta yokohamaensis*. Crustacea, pisces, mollusca, and
elida occur in 47.1%, 29.4%, 8.8%, and 11.7% respectively.

Lastly it should be noted that the frequency percentages of crustacea,
es, mollusca, and annelida against total number, 411, of specimens dealt with
5.5, 26.0, 11.2, and 8.7% respectively (Table 12). This shows that the diet of
mantis-shrimp of the Tokyo Bay is composed of crustacea in overwhelming
ndance and pisces which are a little more than half of crustacea. The rest
poor in comparison to the former two. In this connection it must be added
ewith that there is mud, besides organic matters, ingested in considerably

high percentage (Table 12). But this seems to the present writers to be that it is not taken positively, and appears to be merely eaten by chance together with other things available for diet when the mantis-shrimp is eating foods.

Summarizing above, it may be said that the mantis-shrimp is carnivorous feeding chiefly on such small sized demarsal animals as crustacea, pisces, mollusca, annelida, and others occurring on the same habitat of the mantis-shrimp.

Table 12. Frequency distribution of main food of the shrimp. The figures given in parentheses are showing percentage.

Main food	January	February	March	April	May
Crustacea	11 (26.8)	15 (60.0)	22 (57.9)	21 (53.8)	29 (35.8)
Pisces	14 (34.1)	4 (16.0)	18 (47.4)	11 (28.2)	3 (3.7)
Mollusca	4 (9.8)	5 (20.0)	1 (2.6)	5 (12.8)	1 (1.2)
Annelida	5 (12.2)	4 (16.0)	3 (7.9)	0	1 (1.2)
Mud	22 (53.7)	16 (64.0)	29 (76.3)	21 (53.8)	32 (39.5)

Main food	June	August	September	November	Total
Crustacea	43 (60.6)	6 (20.0)	24 (46.2)	16 (47.1)	187 (45.5)
Pisces	7 (9.9)	17 (56.7)	23 (44.2)	10 (29.4)	107 (26.0)
Mollusca	3 (4.2)	4 (13.3)	20 (38.5)	3 (8.8)	46 (11.2)
Annelida	5 (7.0)	4 (13.3)	10 (19.2)	4 (11.7)	36 (8.7)
Mud	44 (62.0)	7 (23.3)	4 (7.7)	0	175 (42.6)

Above all, crustacea appear to be playing most important role for the diet of the shrimp in question. The crustaceans which make main diet of the mantis-shrimp are found to be *Crangon affinis* De HAAN, *Trachypenaeus curvirostris* (STIMPSON), *Alpheus japonicus* (MIERS), *Metapenaeopsis dalei* (RATHBUN), and *Pilumnoplax vestita* (De HAAN). Those crustaceans, except the fourth, are the most common species in Tokyo Bay. Important fishes among the pisces found in the stomach contents seem to be gobies and flat fishes. It is revealed that *Philine japonica* and *Raeta yokohamaensis*, common in Tokyo Bay, are comparatively important for the diet of the mantis-shrimp. Thus there is a parallelism between amount of the animals ingested as the food of the mantis-shrimp and the abundance of the animals occurring on the same environment of the mantis-shrimp for which the present analysis is made.

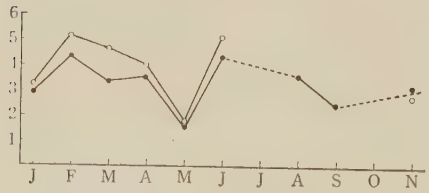

Fig. 16. Monthly change of average volume index (ordinate) of stomach content. Abscissa, months from January to November. Soft marks, female; solid ones, male.

As a method of quantitative analysis of the stomach contents, an index is used. The index, that is called as volume index (VI) of the stomach contents in the present thesis, is expressed by 10 degrees besides 0, measuring the volume of the stomach contents by eyes. Thus the stomachs with full, nearly half, about three-tenths contents and empty ones are indexed as 10, 5, 3, and 0 respectively.

Table 13. Frequency distribution of the volume index (VI) of stomach contents.

	VI	Jan.	Feb.	Mar.	Apr.	May	June	Aug.	Sep.	Nov.	Total (%)
	0	5	4	4	2	21	11			5	52 (27.4)
	1	5		4	7	13	3			6	38 (20.0)
	2	2	2	4	1	4	3			3	19 (10.0)
	3				1	1					2 (1.1)
	4		1			1				2	4 (2.1)
♀	5	4	1	4	2	1	6			2	20 (10.5)
	6			1	1	1					3 (1.6)
	7									2	2 (1.1)
	8	2	5	3	1		3			1	15 (7.9)
	9										0 (0)
	10	2	3	6	4	4	14			2	35 (18.4)
	Total	20	16	26	19	46	40			23	190 (100)
	0	7	2	4	7	19	6	6	12	2	65 (29.5)
	1	4	1	2	3	4	4	10	14	3	45 (20.5)
	2	2		1	1	6	2	1	5	1	19 (8.6)
	3	1	1						9	1	12 (5.5)
	4	1		2	1	1	2	2	3		12 (5.5)
♂	5	2	3		3	2	8	2	3	1	23 (10.5)
	6	1				1	2	2	1		7 (3.2)
	7							1	2	2	5 (2.3)
	8			1	2	1	2		1	1	8 (3.6)
	9							3	1		4 (1.8)
	10	3	2	2	3	1	5	3	1		20 (9.1)
	Total	21	9	12	20	35	31	30	52	11	220 (100)

Frequencies of the index examined monthly are given on the Table 13. As seen from it, a considerable variation is found to exist. A matter of interest in this connection is that the frequencies of the stomach of the index 0 or empty one are not so much different by month as they range 20.0～29.2 in percentage in all months except May. Also it is remarkable that the percentage of May show a very high value (49.3%) in comparison to that of other months.

Table 14. Monthly volume index of stomach contents in average.

Month	♀	♂
Jan.	3.3	2.9
Feb.	5.2	4.3
Mar.	4.6	3.3
Apr.	4.0	3.5
May	1.7	1.5
June	5.1	4.3
Aug.	—	3.5
Sep.	—	2.4
Nov.	2.8	3.2

Monthly change of mean values of the index is shown in the Table 14 and Fig. 16. A glance at the figure reveals that there is a sudden drop in May irrespective of sex, and the values are always, at least in the months, January to June, somewhat larger in female than in male.

9. Discussion

Of the habitat, breeding season, and others of *Squilla oratoria* De Haan, merely some informations have been given by Komai (1924, '27). But no report

has been done of bionomics of this mantis-shrimp basing on concrete data. In the present paper, size-difference by fishing ground, sex-ratio weight-length relation, ponderal index, spawning season, mass-growth, and feeding habit are dealt with. As the result of the present investigation, some findings are obtained as described already under heading of each item. It is revealed after an examination taking material simultaneously that there is a segregation of stock of this mantis-shrimp as younger individuals inhabit shallow waters of the west side of the middle part of Tokyo Bay and older ones live in somewhat deeper waters of the east side of the same part of the Bay. Accordingly it may be said that the places of the west side and the east side of the middle part of Tokyo Bay appear to be nursery and feeding ground of the mantis-shrimp respectively. This inference well agree with fishermen's speaking of this matter. The place considered here to be nursery of the mantis-shrimp lies off the coasts between Kawasaki city and Koyasu, Yokohama city. It is very interesting that the place in question is nursery for the mantis-shrimp, although the place is a part highly contaminated by drainage of many large cities and factories standing mainly on the north-west coasts of the Bay.

With regard to sex-ratio, weight-length relation, and ponderal index, some discussions have been made already in each part of these items. Since there is no need to repeat it in this place.

To know the spawning season of the mantis-shrimp, gonad-weight analysis was undertaken on basis of numerous specimens fished monthly from Tokyo Bay. The result obtained is, as noted already, largely in accordance with the description given by KOMAI (1924, '27).

Growth estimation of this mantis-shrimp is difficult as no age-character is present as is the case with other crustacea. To estimate the mass-growth of the animal, mean lengths of each group found on material of each month are plotted on a graph with body-length in ordinate and with age (month and year) in abscissa. Separation of groups of each month is made by using Harding's method as written already.

Using this graphic method for growth estimation, error may be taken place only in the following respect if it would occur: mean body-length of intermediate group is not plotted correctly according to the age of the mantis-shrimp as it has no age-character. For instance, the mean value of a group of a month of a certain year, which is to be plotted as the upper limit of the month of the year, is put as the lower limit of the month of the next year, or on the contrary, that is to be plotted as the lower limit of the month of the year, is set as the upper limit of the month of the previous year. Specimens for stomach contents analysis must be fixed by formalin or other suitable fixatives as soon as the catch is emptied on deck. Nevertheless the specimens for such purpose in the present investigation are preserved in formalin of about 10% in laboratory after carrying them from the fishing ground as mentioned already. So that several hours are passed until the specimens are preserved. This was, however, inevitable due to only the force of circumstance. In the biological study of *Pandalus montagui* LEACH, MISTAKIDIS (1957) has found that some inactivity in feeding of the prawn in question is present before the period of egg laying. It is very interesting

that nearly the same phenomenon has been found to exist in the present mantis-shrimp too. The inactivity, in this mantis-shrimp, occurs in May, and the main spawning season ranges from June to July as set forth already.

10. Summary

Segregation of the stock of this mantis-shrimp is found to exist.

Sex-ratio shows a considerable extent of variation throughout the year ranging from 38.7 to 112.5 (77.27 on average).

Weight (W)-length (L) relationship is expressed by the following formulae: $W=0.02313\ L^{2.8131}$ for January-material, $W=0.01141\ L^{3.0716}$ for April-material, $W=0.01908\ L^{2.8420}$ for July-material, and $W=0.01462\ L^{2.9646}$ for November one. There is no difference between sexes.

Ponderal index betokens no gradual change in relation to body-length irrespective of sex at least within the limit from 9 cm to 17 cm in body-length, although there is considerable individual variation. The index is largest in January and December, smallest in June in both sexes, but smaller in female than that in male throughout all months of the year. It becomes gradually larger from June toward December and January, and decreases from month to month toward May.

Spawning season appears to run for a period from the middle of May to early of July, and is in its height in June.

The mean body-lengths of each age-group run, within the limit of the present material, as follows: 5.0～7.2 cm in 0-age group, 7.5～11.3 cm in I-age group, and 9.4～14.4 cm in II-age group irrespective of sex. The largest average body-length of III-age group is 15.06 cm in female, 14.35 cm in male. The life span appears to be about 3 years and 9 months in female, and 3 years and 5 months in male.

The mantis-shrimp is carnivorous feeding chiefly on small sized bottom animals, namely crustacea, pisces, mollusca, annelida, and others. An inactivity in feeding is found to exist previous to the main spawning season as is the case with *Pandalus montagui* Leach.

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Journal of the Tokyo University of Fisheries, Vol. 45, No. 1, 1959

A GROWTH-STUDY OF *HEMIRAMPHUS SAJORI* (T. & S.) BY SCALE AND SIZE-COMPOSITION

Jin Hattori and Masao Seki

(Received Sept. 15, 1958)

The present account deals with a growth-study by scale and size-composition analysis of *Hemiramphus sajori* (T. & S.) collected in different months from various localities of Japan: Tokyo Bay, Sagami Bay and coasts of Aichi and Mie Prefectures.

Before proceeding any further, authors take this opportunity of expressing their hearty thanks to Professor Dr. Itsuo Kubo of our University, without whose constant guidance this project would have been impossible. Acknowledgement is also make to Dr. Nakaroku Nakamura of the Ikawazu Fisheries Laboratory of the Tokyo University and Mr. Kiyoshi Suzuki of the Prefectural University of Mie by whom some specimens used in this work were secured and kindly sent to us.

Material and Method

The material consists of 317 individuals caught from various localities as shown in the Table 1. The body-lengths are ranging from 4.1 cm to 29.5 cm.

Table 1. Matters concerned for material examined in this study.
NI, number of individuals; NIS, number of individuals, from which scales taken.

Locality	Date	NI	NIS	Body-length (BL) in cm	Average of BL in cm
Ikawazu (Aichi)	1940 June 23	26	26	4.1–7.3	5.38
Ikawazu (Aichi)	1942 July 12	17	0	7.1–10.7	8.29
Aritake (Mie)	1952 June 23	20	0	4.3–8.8	6.35
Urayasu (Chiba)	1953 Apr. 28	2	1	20.7–29.5	25.1
Kurihama (Kanagawa)	〃 May 4	38	0	15.5–19.1	16.63
Urayasu (Chiba)	〃 May 25	147	147	14.6–26.8	17.61
Kaneda (Kanagawa)	〃 Aug. 21	1	0	11.9	11.9
Kurihama (Kanagawa)	〃 Sept. 10	1	1	20.2	20.2
Otsu (Kanagawa)	〃 Sept. 16	19	16	17.3–26.2	21.26
Kamakura (Kanagawa)	〃 Sept. 20	47	8	18.2–24.3	20.55
Total		317	199		

Measurement and sampling of the scales were undertaken on specimens fixed by about 10% formalin solution commercially sold. The body-length is given as a length covering from the top of the upper jaw to the base of the caudal fin. As the scales of this fish are apt to fall off, 199 specimens out of total number

of specimens, 317 individuals, were available for purpose of reading. A number of scales was taken from the upper part of the lateral band of the body and the part a little back to the tip of pectral fin of each individuals. Then those scales were set into preparation by the KUBO-HATTORI method[1].

The scale-length (S) and the distance (r) between focus and resting zone (or unnulus in this case) of scale were measured by means of the method shown in the Fig. 1.

Fig. 1. Explanation of measuring method of the scale of *H. sajori*. The scale taken from a specimen of 29.5 cm in body-length.

Body length when scale firstly appeared

The smallest specimen submitted for the present inspection, 4.1 cm in body-length, is already provided with minute scales on the lateral surface of the body. The scales of the specimen are furnished with single circulus, and the scale-length (S) of those scales measures about 0.2 mm. Judging from the matter given above, the body-length, at which the scale firstly developed of this fish, may be infered to be about 3.0 cm.

Position and time of resting zone formation

In only 30 specimens out of 199 available specimens, their scales are found having one resting zone on the outer surface of those. No specimens are with scales provided with more number of resting zone. The r of those ranges 0.8-1.9 mm, and is 1.2-1.4 mm in mode. As seen in the Table 2, $\bar{r}$ of each lot of material is 1.2 mm in most cases.

To reveal the time of resting zone formation, an analysis was made due

Table 2. Distance (r) from focus of scale to the outer edge of resting zone. NI, number of individuals; $\bar{r}$, average of r; *, based on single datum.

Locality	Date	NI	Range of r	$\bar{r}$
Urayasu	Apr. 28	1	1.9 (mm)	*1.9 (mm)
Urayasu	May 25	4	0.9–1.3	1.1
Kurihama	Sept. 10	1	1.2	*1.2
Otsu	Sept. 16	16	0.8–1.7	1.2
Kamakura	Sept. 20	8	0.8–1.8	1.2
Total		30		

Table 3. Number of individuals examined (NI) from which scales avairable for the present study were taken.

Locality	Date	NI		
		With 1 resting zone	Without resting zone	Total
Ikawazu	June 23	0	26	26
Urayasu	Apr. 28	1	0	1
Urayasu	May 25	4	143	147
Kurihama	Sept. 10	1	0	1
Otsu	Sept. 16	16	0	16
Kamakura	Sept. 20	8	0	8
Total		30	169	199

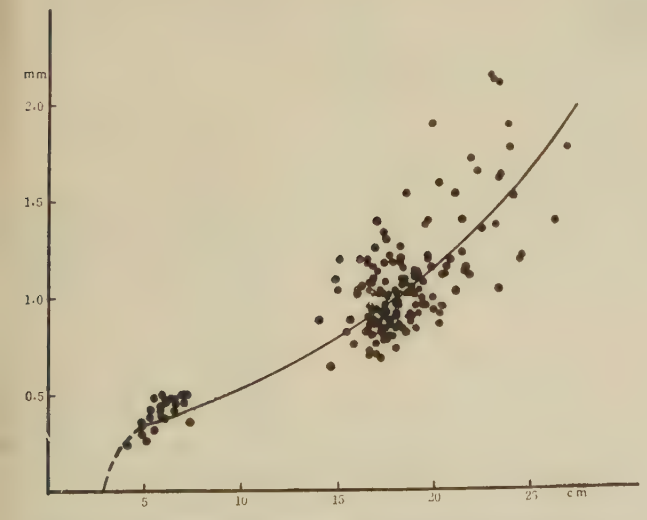

Fig. 2. Showing relationship between body-length in cm and scale-length in mm.

to the presence or absence of the resting zone on the scale as to all the specimens available for this objective. The result is given on the Table 3. As seen from the table, the resting zone does not exist on almost scales of the April-June-material, but there are found only scales with resting zone in the September-material.

On the other hand, the resting zone not yet formed on the scales of most specimens of the

May-material except the sepcimens taken on June 23 from Aritaki and Ikawazu, which appear to be of O-age born in the spring judging from their body-length composition. It follows therefore that the resting zone of this fish seems to be embodied during a period of the summer from June to August.

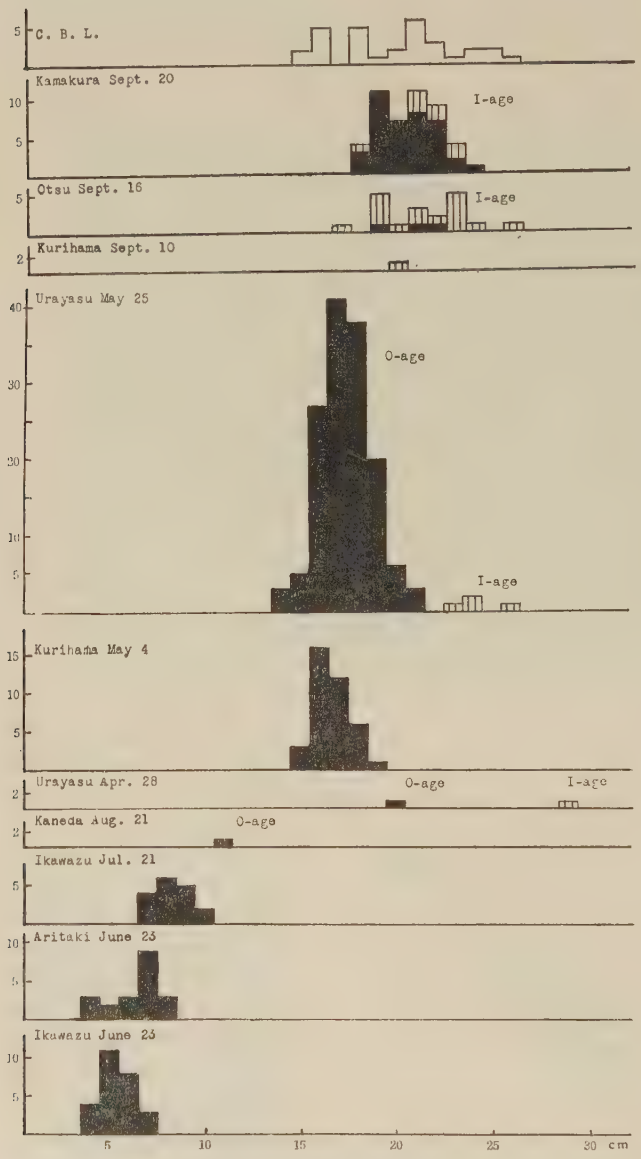

Fig. 3. Showing body-length composition which is put in order of date. Abscissa, body-length in cm; ordinate, frequencies; black part, fish having non-resting zone on scale; striped part, fish having one resting zone on scale; C.B.L., calculated body-length.

The relationship between body-length (L) and scale-length (S) may be expressed by the following formula, $S = 0.025e^{0.076L}$. The relation is seen in the Fig. 2. The body-length when the resting zone is achieved is calculated using the formula given above. It runs within a limit from 15.3–26.2 cm, 20.5 cm on average, and its frequency distribution is shown in the Fig. 3. The distribution is similar to that of the September-material. This agrees well with the fact that the time of the resting-zone-formation infered from the scale analysis afore mentioned is of a period from June to August.

Growth and Age

As betokened in the Fig. 3, a successive growth is seen in the body-length compositions based on material collected from various localities in different dates. The body-length of specimens obtained on June 23 from Ikawazu, on the same day from Aritake, and on July 12 from Ikawazu

ranges 4–7, 4–8, and 7–10 cm respectively. A specimen secured on August 21 at Kaneda measures 11 cm in body-length. Then, the above specimens may be infered to be O-age group hatched out in the spawning season which is probably April or May[2].

The Kurihama-specimens obtained on May 4 are ranging 15–19 cm in body-length. The Urayasu-specimens collected on May 25 are measuring 14–21 cm long. As these specimens have no resting-zone in their scale, they appear to belong to 0-age group being full one year since their hatching.

Also a specimen taken on April 28 from Urayasu is 29.5 cm long, and it is the largest specimen among ones dealt with in the present investigation. Four specimens out of Urayasu-specimens collected on May 25 are ranging 23–25 cm. And then, the body-length of specimens taken on September 10 from Kurihama, on Sept. 16 from Otsu, and on Sept. 20 from Kamakura ranges, 20, 18–26, 19–24 cm respectively. Above specimens may be infered to be those belonging to I-age group, because they have a resting-zone in their scale.

Uchida[3] has made a information on the growth of this fish dealing with a material collected monthly in the vicinity of Pusan, Korea during the years 1929–'30. He showed the growth by means of overall length of the fish largest among specimens of each month. The total length of the fish of O-age group and that of I-age one, according to him, measures a little more than 20 cm and 30 cm respectively in about October.

Table 4. A comparison in total length (cm) between results taken by Uchida and the present authors.

Age	Months	Uchida	The present authors
O	June	6	10.0
	Jul.	12	12.5
	Aug.	15	13.7
I	Apr.	24.5	23.4
	May	25	25.0
	Sept.	32	29.4

With regard to growth of this fish, a comparison of the O-age and I-age groups were made between both materials of Uchida and the present authors as shown in the Table 4. A glance at the table, it may be recognized that the figures of both Uchida and the present authors nearly agree with each other.

Summary

(1) The scales of this fish appear to be firstly formed when the fish measure about a length of 3.0 cm.

(2) The radius from focus to the resting zone (only one resting zone is found to exist in all samples treated) of the scales ranges between 0.8 and 1.9 mm, 1.2 mm on average.

(3) The resting zone is infered to be achived during June to August.

(4) The relationship between body-length (L) and scale-length (S) may be expressed by the following formula, $S=0.025e^{0.076L}$.

(5) The 0-age fish seems to become 15–20 cm and 20–25 cm long at April or May and September or October of the next year respectively.

(6) The result of the growth study made by UCHIDA on specimens secured at Pusan, Korea nearly agrees with that of the present scrutiny.

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Journal of the Tokyo University of Fisheries, Vol. 45 No. 1, 1959

ON A NEW COMMENSAL COPEPOD, *MYTILICOLA MACTRAE* N. SP. OBTAINED FROM THE INTESTINE OF *MACTRA VENERIFORMIS* REEVE

Toshikazu Hoshina and Ren Kuwabara

(Received Sept. 15, 1958)

A species of cyclopoid copepods was found by Mr. Y. Sugiura of Tokyo University of Fisheries, in the intestine of *Mactra veneriformis*, at Kisarazu, Chiba Prefecture and by his courtesy, the specimens (♀ 2, ♂ 1) were placed at our disposal. For the study, we also collected the copepods at the same locality. As the copepod appears to be new to science, we give a description of it under the name of *Mytilicola mactrae*.

We express our hearty thanks to Professor Dr. Satyū Yamaguti of Okayama University, for his aid rendered in the supplying of the literature.

Mytilicola mactrae n. sp.

(Textfig. 1, Pl. I, Figs. 1–10, Pl. II, Figs. 11–22)

Materials.—In addition to the specimens placed (Dec. 8, 1956) by Mr. Sugiura, the others were collected by ourselves. Sixty nine individuals of the bivalves (*Mactra veneriformis*, shell length 22–35 mm) collected on Jan. 5, 1958 at Kisarazu were examined and of these thirty-four were found carrying the copepods. Of 46 specimens (♀ 38, ♂ 8) of the copepods were obtained from them.

Descriptions. — FEMALE: Body elongated, 3.7～4.6 mm long, bearing six pairs of dorsolateral processes (a pair on head, the rests on thorax), without cuticular division denoting thoracic or abdominal somites, reddish in living specimens (Figs. 1～2). Head 0.23～0.34 mm long by 0.30～0.45 mm broad at the broadest part, with a median and a pair of bilateral dorsal ribs; median dorsal rib bifurcating at its posterior extremity and combined with bilateral ribs (Fig. 3). Nauplius eye dark reddish, 0.15～0.24 mm apart from frontal margin of head. Thorax 2.7～3.6 mm long by 0.37～0.54 mm broad at genital segment. Genital segment somewhat swollen bilaterally. Egg strings pale reddish, 1.54～2.91 mm long, containing about 16～54 eggs in two rows but one row generally in the distal portion. Egg ellipsoidal, 0.11～0.16 mm by 0.09～0.14 mm. Abdomen slightly narrowed posteriorly, 0.63～1.20 mm long 0.19～0.29 mm broad at anterior end, terminating into two small caudal rami. Caudal rami cylindrical, divergent each other, 0.10～0.15 mm long by 0.04～0.06 mm broad at base; each with a small spine on its outer side at near distal portion and two small spines at tip.

First antenna 4-segmented (Fig. 4), 0.10～0.13 mm long by 0.05～0.07 mm broad at proximal part. First segment the largest, bearing well developed chitin-frame on its broad base and 11～13 small spines on the antero-ventral surface. Subsequent segments armed with spines or setae as follows: second 3～5; third 1～3; fourth 4～7, of which 2～4 at tip. Second antenna consisting of four segments; distal segment being stout claw (Fig. 5).

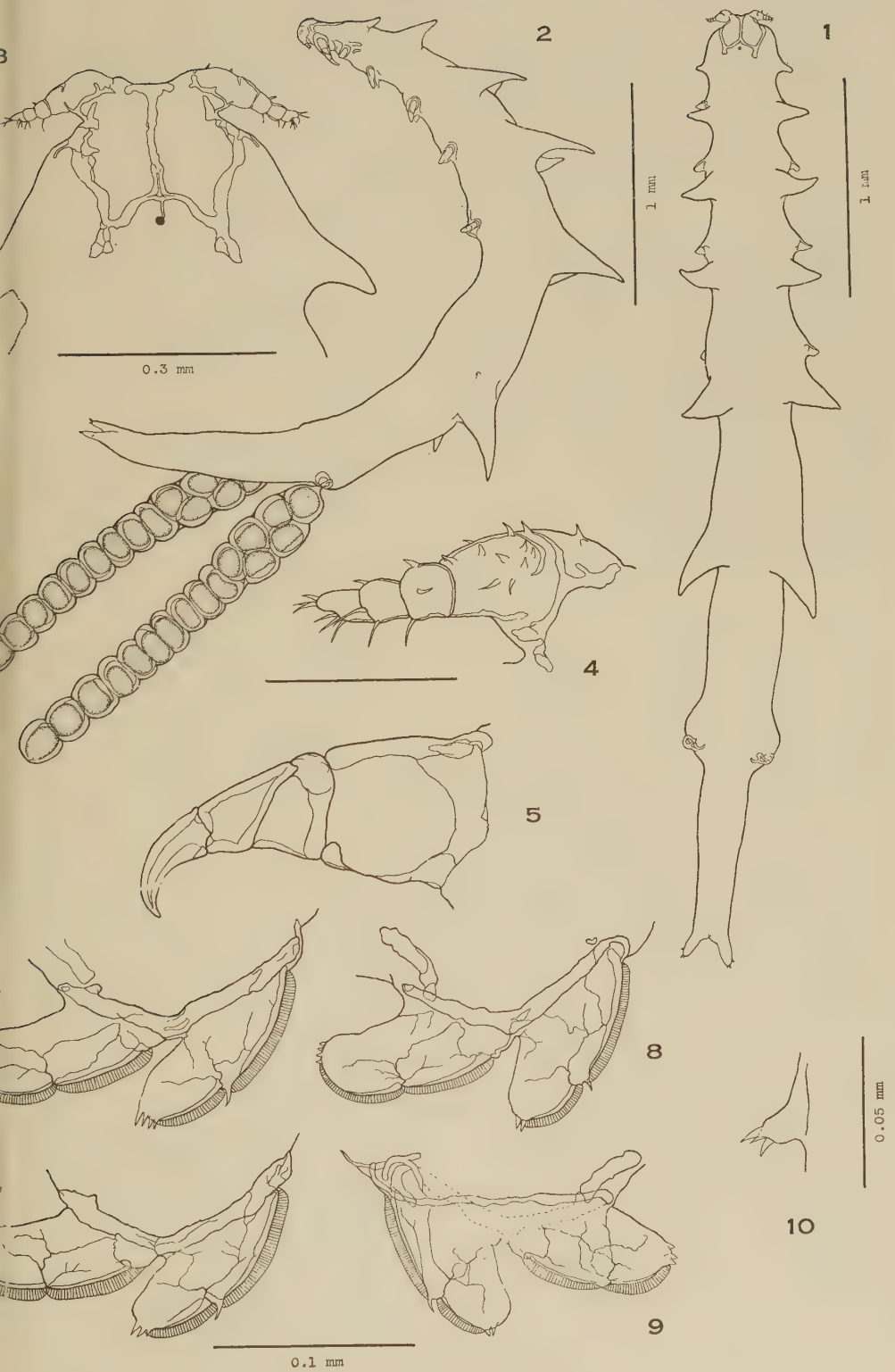
PLATE I.

Figs. 1–10. *Mytilicola mactrae* n. sp., female

Fig. 1. Dorsal.
Fig. 2. Other specimen, lateral.
Fig. 3. Head, dorsal.
Fig. 4. First antenna, ventral.
Fig. 5. Second antenna, dorsal.
Fig. 6. First leg, ventral.
Fig. 7. Second leg, ventral.
Fig. 8. Third leg, ventral.
Fig. 9. Fourth leg, dorsal.
Fig. 10. Fifth leg, ventral.

Notice. The scale placed between Fig. 4 and 5 indicates 0.1 mm.

PL. I.



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ZOOGEOGRAPHICAL STUDIES ON THE DEMERSAL FISHES OF THE TOKYO BAY*

Kazunori TAKAGI

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Entering upon the co-operative studies on the fishery resources and their environment of the Tokyo Bay for 1954–56, our research group carried into effect during last spring to last autumn 1954, the benthic surveys of the bay, and collected by trawling, quantitatively as possible, various animals including a great number of demersal fishes. (cf. KUBO and ASADA 1957). The present writer gives here a zoogeographical analysis of the bay, based on the fish material above mentioned.

The fish fauna of the region has not been quantitatively studied, except of the work by YAMANOUCHI *et al.* (1942). Their investigation, however, is not related only to local surveys of the estuary of the Edo River, Omori, and Haneda, Tokyo, and off Kawasaki, Kanagawa Pref. Investigations of more or less larger scale have been made in the bay but on the principal and epi-faunas. It is then first and in the largest scale at any rate that our surveys were carried out in the bay of the demersal fishes as a moving fauna.**

The hydrographical and geographical conditions in the bay are given by SUDA *et al.* (1931) and MASUI (1934) etc. in general, and by KUBO and ASADA (1957: 252–253, Tab. 1) especially for our surveys in question.

The Tokyo Bay here mentioned is to be geographically called the Gulf of Tokyo (Tokyo Kaiwan), which may be divided into two regions: Tokyo Bay, *s. str.*, and Uraga Strait. The Tokyo Bay in the narrow sense is given a definition as the region north of a limiting line connected between headlands of Katsurikizaki, Yokosuka, Kanagawa Pref., and Futtsuzaki, Chiba Pref.; it is another region of the Uraga Strait that is restricted northwards by this line, and southwards by that between Jogashima, Kanagawa Pref., and Sunosaki, Chiba Pref. Our investigation is related to so-called Tokyo Bay in the wide sense.

I wish to express my deep gratitude to Prof. Itsuo KUBO, Director-in-chief of the survey, under his supervision the present study was made. My thanks are also due to Dr. Takashi INO, Technician of the Tokai Regional Fisheries Research Laboratory, Tokyo, and a biological research staff of the survey, who offers kindly his samples in my disposal, and to Mr. Tsutomu MASUDA, who helped to classify the samples. The present study is supported in part by a

* Read preliminarily before the vernal meeting for 1956 of the Japanese Society of Scientific Fisheries, Tokyo, on April 5, 1956.

** The principal fauna means both the essential and accessory faunas. The essential fauna is the dominant or characteristic species of bionomical facies. The accessory fauna are formed by other sedentary animals. The epifauna consists of the associated, commensal or parasite species, if free or fixed, living on the above animals. The moving fauna is the animals definited as the necton. (LE DANOIS 1948: 78.)

Grant-in-aid for the Co-operative Research (Agriculture) from the Ministry of Education, 1954–56.

MATERIAL AND METHODS

The survey was brought by day three times for the period: May 27-June 1st, August 30-September 5, and December 7–12, 1954, at the 53 stations* chosen in the bay, beneath the level of 5 m. depth, as shown in Fig. 1.

The samples are all taken aboard the Tokai Regional Fisheries Research Laboratory research boat " Takamaru," (Captain Takeo KOYAMA, 10.56 G. T., 40 HP,) by trawling for five minutes at a time a small net having the beam of 2.2 m. length, and 3.6 cm. mesh, or in stretched measure inside the knots, at the mouth, and 1.4 cm. mesh at the bag. This sampling intends that the catches of unit trawling represent the relative density of animal communities at each station.

By an experimental trawling in the second survey at the Station No. 63, where is on sand, 7–9 m. in depth, the net is found to rake for unit time and speed the bottom of 250 m. distance, or 550 square metres accordingly. If this data is here accepted, the trawling area in the bay *s. str.* is calculated as about 24,000 square metres. As the correponding area of 5 m. or more depth, related to our surveys, is given as 834.25 square kilometres, those raked areas equal nearly a forty thousandth of the latter. An observation at the time by Dr. INO, relating exclusively to the yellow star-fish, *Astreas amurensis* LÜTKEN, says that the net catches the animal of 17.4% found on the area in question.

The present surveys are to be limited only to deeper benthic fauna of the region, as mentioned above, because of tonnage of our research boat, and form of the fishing appliance which we were used. It may be another problem, however, if these catches are concluded to be benthic indeed. As we have no sufficient data for the matter, all samples from the surveys are equally treated with here. (cf. LE DANOIS 1948: 77.)

As a catch at the first survey (Station No. 73) is enlisted a Japanese horse mackerel, *Trachurus japonicus*, which has been supposed to live in middle to lower layer in the sea; it is recently that the fish is found to have some reasonably benthic behavior. (KUBO and YOSHIHARA 1957: 216.)

In this study are presumed some sections of the bay, by means of horizontal and vertical subdivision. The horizontal subdivision is made both latitudinally and longitudinally; latitudinal three sections A–C, and longitudinal two sections W and E.

The Section A embraces 32 stations of Nos. 1–61; its bottom is represented by fine mud. The Section B includes 11 stations of Nos. 63–82, represented by sand mud. The Section C covers 10 stations of Nos. 83–92, the bottom of which is represented by coarse sand. (cf. SHIMADZU and YAMANE 1948: 52, fig. 1.)

The longitudinal and vertical subdivisions are subordinative, and related to 43 stations of the latitudinal Sections A and B. (Table 1.)

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* These 53 stations are selected from 92 ones newly schemed by our staff for the survey. Fifty-two stations are observed in the second survey, because one of them (Station No. 69) is occasionally omitted at the time.

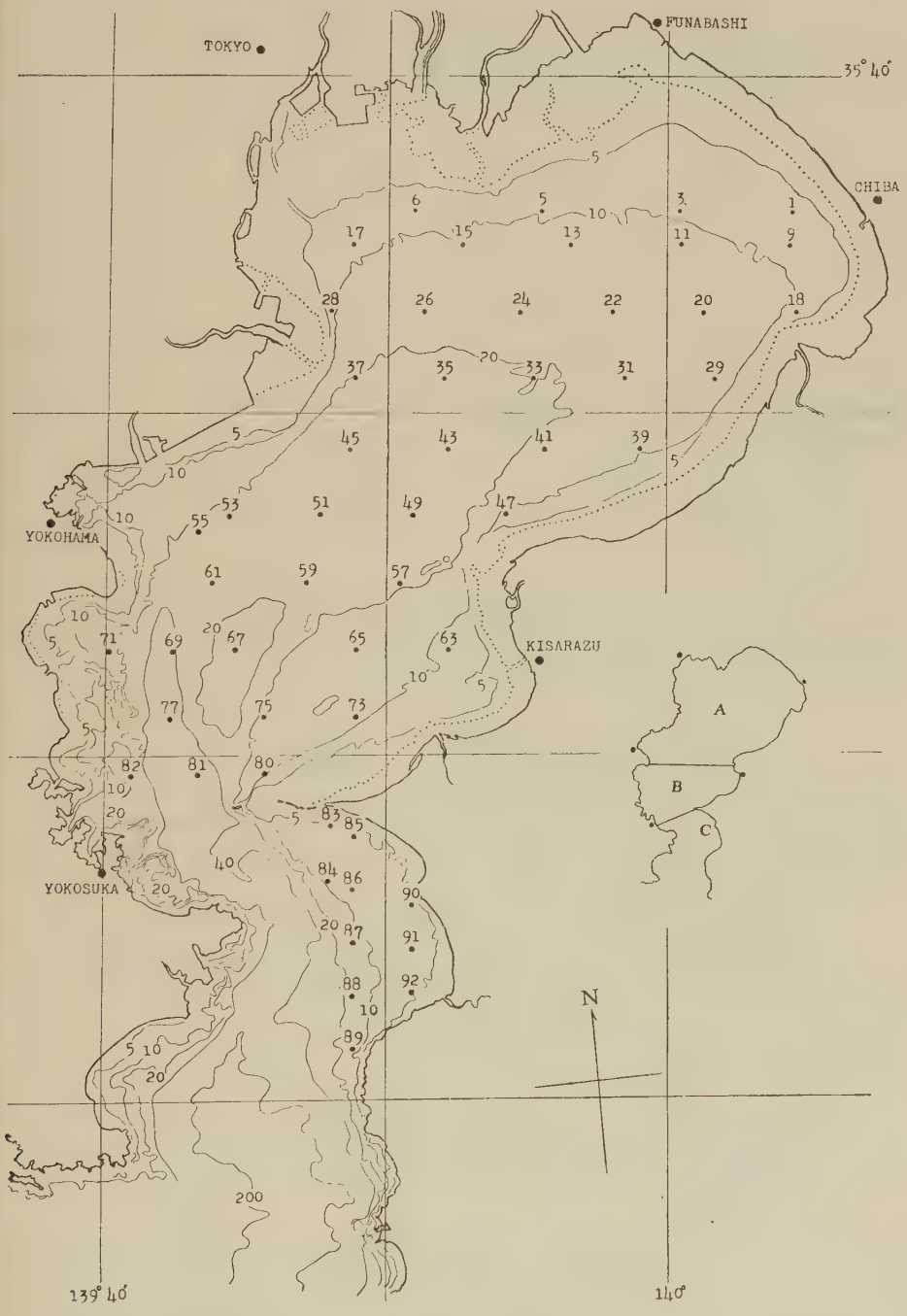

Fig. 1. The Tokyo Bay and the sampling stations of our surveys. The principal sections A, B and C shown in right. (Based on the Hydrographic Department, Maritime Safty Board of Japan, Chart No. 90; after KUBO and ASADA 1957.)

Table 1. Interrelationships of the principal (A and B) and subordinative (W, E, M and N) sections. NG, neglected medial stations; TL, total. Number of stations in the summer survey in parentheses.

	W	E	NG	M	N		W	E	NG	TL
A	15	14	3	21	11	M	9	16	3	28
B	5 (4)	4	2	7	4 (3)	N	11 (10)	2	2	15 (14)
TL	20 (19)	18	5	28	15 (14)		20 (19)	18	5	43 (42)

Regarding with longitudinal sections, some medials stations on latitudinal raws of them are omitted. They are 5 stations of Nos. 13, 33, 59, 75 and 83. The Section W consists then of western 20 (19 in the summer survey) stations, while the Section E of estern 18 ones.

Of the vertical subdivision, those stations are classified on chart by the level of 20 m. depth. The 28 stations above the level belong to the Section M, and deeper 15 stations to the Section N. The latter ones are mostly of less than 40 m. depth.

By the way, SHIMADZU and YAMANE (1948) recognize in the bay some types based on the seasonal change of bed temperature, which is related almost to the Sections A and B, here mentioned. The Section A is represented by their Types A–C, and the Section B by the Types D and E, in the case.

RESULTS

1. Benthic fishes of the Tokyo Bay

The fishes catched by our surveys are found to be of 55 species as a whole, and enlisted as follows.

A. Dasyatidae (FP*):
   1. *Dasyatis akajei* (MÜLLER et HENLE), aka-ei, (A*).
   2. *Urolophus aurantiacus* MÜLLER et HENLE, hirata-ei (A).
   3. *Gymnura japonica* (TEMMINCK et SCHLEGEL), tsubakuro-ei (A).

B. Synodontidae (FP):
   4. *Trachinocephalus myops* (SCHNEIDER), oki-eso (A).

C. Fistulariidae (PE):
   5. *Fistularia villosa* KLUNZINGER, aoyagara (A).

D. Syngnathidae (PF):
   6. *Syngnathus schlegeli* KAUP, yoji-uwo (C).
   7. *Hippocampus japonicus* KAUP, sangotatsu (C).
   8. *Hippocampus* sp. (A or C).

* PF, BE and FP, referred to the trophic level to which the family concerned is supposed to belong. PF plankton feeders; BE, benthos eaters; FP, fish predators.

A and C, referred to the TANAKA (1931)'s lists A and C. A, species in southern waters of Japan; C, species found throughout the land. Here included some fishes classified by other sources. (See § 7a and b.)

E. Carangidae (PF):
9. *Trachurus japonicus* (Temminck et Schlegel), ma-aji (A).
F. Mullidae (BE):
10. *Upeneus bensasi* (Temminck et Schlegel), himeji (A).
G. Apogonidae (BE):
11. *Apogon lineatus* (Temminck et Schlegel), tenjikudai (A).
12. *Apogon kiensis* Jordan et Synder, teppo-ishimochi (A).
H. Serranidae (FP):
13. *Epinephelus septenfasciatus* (Thunberg), mahata (A).
I. Scianidae (BE):
14. *Johnius belengeri* (Cuvier et Valenciennes), konibe (A).
J. Parapercidae (PF):
15. *Cilias pulchella* (Temminck et Schlegel), toragisu (A).
K. Callionymidae (BE)
16. *Callionymus* fishes, mostly of *C. lunatus* Temminck et Schlegel, nezuppo (C).*
L. Pholidae (BE):
17. *Enedrias nubulosus* (Temminck et Schlegel), gimpo (C).
M. Gobiidae (BE):
18. *Lubricogobius exiguus* Tanaka, mijinbenihaze (A).
19. *Tridentiger trigonocephalus* (Gill), shimahaze (C).
20. *Rhinogobius gymnauchen* (Bleeker), himehaze (C).
21. *Rhinogobius pflaumi* (Bleeker), sujihaze (C).
22. *Acanthogobius flavimanus* (Temminck et Schlegel), mahaze (C).
23. *Pterogobius zacalles* Jordan et Snyder, ryuguhaze (C).
24. *Chaeturichthys sciistius* Jordan et Snyder, komochijako (C).
25. *Chaeturichthys hexanema* Bleeker, akahaze (C).
26. *Sagamia geneionema* (Hilgendorf), sabihaze (A).
27. *Heteroplopomus barbatus* (Tomiyama), niramihaze (A).
N. Labridae (BE):
28. *Halicoerus poecilopterus* (Temmick et Schlegel), kyusen (A).
O. Aluteridae (BE):
29. *Stephanolepis cirrhifer* (Temminck et Schlegel), kawahagi (A).
30. *Rudarius ercodes* Jordan et Snyder, amimehagi (A).
P. Ostraciontidae (BE):
31. *Lactoria diaphamus* (Bloch et Schneider), umisuzume (A).
Q. Scorpaenidae (BE):
32. *Sebastes inermis* Cuvier et Valenciennes, mebaru (A).
33. *Sebastiscus marmoratus* (Cuvier et Valenciennes), kasago (A).
R. Congiopodidae (BE):

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* To the samples of *C. lunatus* may be accidently included small number of other *Callionymus* species, at sample classification of the spring and summer surveys. I dare to include five specimens of *Callionymus richardsoni* Bleeker of the autumn survey positively to this group, because it is of small number, and that it seems meaningless to treat rigidly with them only. The samples of the first two surveys had not been recheckable, before our examination was over.

34. *Hypodytes rubripinnis* (TEMMINCK et SCHLEGEL), ha-okoze (A).

S. Hexagrammidae (BE):

35. *Hexagrammos otaki* JORDAN et STARKS, ainame (C).

T. Platycephalidae (BE):

36. *Platycephalus indicus* (LINNAEUS), kochi (A).
37. *Suggruncus meerdervoorti* (BLEEKER), megochi (A).
38. *Onigocia spinosa* (TEMMINCK et SCHLEGEL), onigochi (A).

U. Triglidae (BE):

39. *Chelidonichthys kumu* (LESSON et GARNOT), hôbô (A).

V. Bothidae (BE):

40. *Paralichthys olivaceus* (TEMMINCK et SCHLEGEL), hirame (C).
41. *Pseudorhombus cinnamoneus* (TEMMINCK et SCHLEGEL), ganzobirame (A).
42. *Tarphops oligolepis* (BLEEKER), aramegarei (A).
43. *Engyprosopon ui* (TANAKA), uidaruma (A).
44. *Engyprosopon grandisquama* (TEMMINCK et SCHLEGEL), darumagarei (A).
45. *Crossorhombus valderstratus* (ALCOCK), Kobedarumagarei (A).

W. Pleuronectidae (BE):

46. *Pleuronichthys cornatus* (TEMMINCK et SCHLEGEL), meitagarei (C).
47. *Limanda yokohamae* (GÜNTHER), makogarei (C).
48. *Kareius bicoloratus* (BASILEWSKY), ishigarei (C).

X. Soleidae (BE):

49. *Heteromycteris japonicus* (TEMMINCK et SCHLEGEL), sasa-ushinoshita (A).
50. *Zebrias zebra* (BLOCH et SCHNEIDER), shima-ushinoshita (C).

Y. Cynoglossidae (BE):

51. *Rhinoplagusia japonica* (TEMMINCK et SCHLEGEL), kuro-ushinoshita (C).
52. *Areliscus interrupus* (GÜNTHER), genko (A).

Z. Lophiidae (FP):

53. *Lophius litulon* (JORDAN), ki-anko (C).
54. *Lophiomus setiferus* (VAHL), anko (C).

AA. Sp. unknown. Juvenile fish catched at the Stations Nos. 73 and 80 in the autumn survey.

Of the seasonal catches, the number of species is most in spring and shows a gradual decrease to autumn. They are of 35 species in the spring survey, of 30 species in the summer survey, and of 27 species in the autumn survey. (Table 2.)

Table 2. Special (SP) and common (COM) species composition of the seasonal catches, in spring (P), summer (E) and autumn (A) surveys. EA, summer and autumn; PA, spring and autumn; PE, spring and summer; PEA, all seasons: spring, summer and autumn.

	SP	COM				TL
		PEA	PE	EA	PA	
P	15	15	2	—	3	35
E	11	(15)	(2)	2	—	30
A	7	(15)	—	(2)	(3)	27

The tendency is also shown in the number of species exclusively catched in each survey. They are of 15, 11, and 7 species in respective surveys. It may be more characteristic, because spring special species is equal in number to 43% of all, and this percentage drops remarkably to 27% in autumn catch.

The fifteen species in the spring survey are: *Urolophus aurantiacus*, *Hippocampus* sp., *Trachurus japonicus*, *Apogon kiensis*, *Lubricogobius exiguus*, *Rhinogibus gymnauchen*, *Heteroplopomus barbatus*, *Hexagrammos otaki*, *Platycephalus inducus*, *Onigocia spinosa*, *Chelidonichthys kumu*, *Pseudorhombus cinnamoneus*, *Crossorhombus valderostratus*, *Lophius litulon*, and *Lophiomus setiferus*. The 11 species of the summer survey are: *Dasyatis akajei*, *Gymnura japonica*, *Fistularia villosa*, *Upeneus bensasi*, *Johnius belengeri*, *Haricoerus poecilopterus*, *Stephanolepis cirrhifer*, *Lactoria diaphamus*, *Sebastiscus marmoratus*, *Engyprosopon ui*, and *Zebrias zebra*. The 7 species in the autumn survey are: *Trachinocephalus myops*, *Syngnathus schlegeri*, *Tridentiger trigonocephalus*, *Sebastes inermis*, *Suggruncus meerdervoorti*, *Tarphops oligolepis*, and sp. unknown.

The common species to these seasonal surveys are fifteen in number. Two species are common between the spring and summer surveys, two and three ones between the summer and autumn, and the spring and autumn surveys respectively.

The 15 common species to the three surveys are: *Hippocampus japonicus*, *Apogon lineatus*, *Callionymus lunatus*, *Rhinogobius pflaumi*, *Acanthogobius flavimanus*, *Pterogobius zacalles*, *Chaeturichthys sciistius*, *Chaeturichthys hexanema*, *Sagamia geneionema*, *Rudarius ercodes*, *Paralichthys olivaceus*, *Pleuronichthys cornatus*, *Limanda yokohamae*, *Kareius bicoloratus*, and *Areliscus interrupus*. The following species are common to pairs of surveys; the common species of the spring and summer surveys are *Cillias pulchella*, and *Enedrias nubulosus*, those of the summer and autumn surveys are *Epinephelus septenfasciatus* and *Rhinoplagusia japonica*, and three species: *Hypodytes rubripinnis*, *Engyprosopon grandisquama*, and *Heteromycteris japonicus*, are common to the spring and autumn surveys.

2. Number of species occurring per station

The species occurring for station is 0-10 in number through seasons and sections, 4 in mode, and 3.3 in average. (Fig. 2.) The average number of species is given in detail in the Tables 3 and 4.

Comparing it among the latitudinal sections, the benthic fishes are more in species, but settled in the Section A, while the seasonal change is much more recognized in the Section C, and the Section B intermediate area. The fishes appear to be more in species at the Sections A and B (3.4 in average), than at the Section C (3.0), and to decrease from spring (3.7 in average) to autumn (2.9). Through seasons the Section A (5.5) is less in number of species than the Sections B (7.7) and C (7.1).

As for the longitudinal difference, the Section W (3.0 in average) is generally less in species than the Section E (3.9). Between the vertical subdivision, no remarkable tendencies appear to be recognized, but the Section M (3.5 in average) may be said more in species than the Section N (3.1). When these subordinative sections

are divided into the principal sections, A and B, these general trends are found to remain in the latter, except of the case in summer, especially in the Section B.

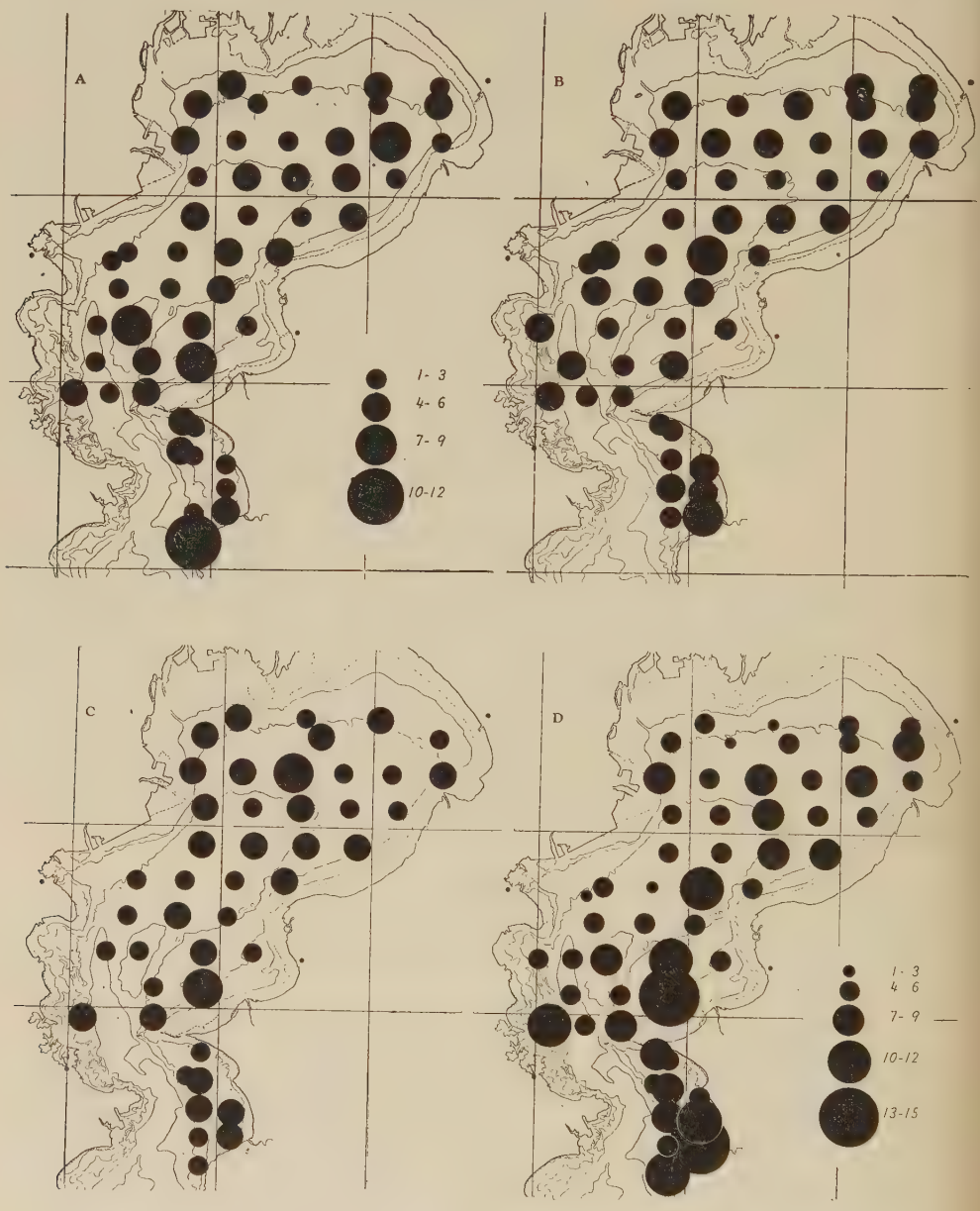

Fig. 2. Distribution maps of number of species catched in spring (A), summer (B) and autumn (C) surveys, and through seasons, spring to autumn (D). Legend common to A, B and C on upper left.

Table 3. Average number of species for station in the bay as a whole (BAY), and the sections. AV, average number of three seasons; P–A, through seasons, spring to autumn.

	BAY	A	B	C	W	E	M	N
P	3.7	3.7	4.1	3.4	3.1	4.8	4.0	3.3
E	3.3	3.5	3.0	2.8	3.0	3.9	3.2	3.6
A	2.9	2.9	3.0	2.8	2.8	3.1	3.3	2.3
AV	3.3	3.4	3.4	3.0	3.0	3.9	3.5	3.1
P–A	6.2	5.5	7.7	7.1	4.9	7.3	6.2	4.1

Table 4. Average number of species for station in the Sections A and B, belong to those of W, E, M and N.

	W		E		M		N	
	A	B	A	B	A	B	A	B
P	3.1	3.0	4.6	5.5	3.8	4.7	3.5	3.0
E	2.7	4.0	4.1	3.0	3.3	2.7	3.6	3.7
A	2.9	2.4	2.6	4.5	3.2	3.4	2.4	2.3
AV	2.9	3.1	3.8	4.7	3.5	3.6	3.2	3.0
P–A	4.3	7.3	6.7	9.5	5.6	8.1	5.3	6.7

3. Number of species classified per section

The seasonal distribution of species classified by latitudinal sections is 11–21 in number, and shows general trends of lower number in the Section A (12.7 in average) than in the Sections B and C (16.3), and of seasonal decrease from spring (18.3 in average) to autumn (12.0) surveys. (Table 5.) The seasonal trends are similar to those in the number of species for station, but the regional trends

Table 5. Seasonal and total number of special and common species occurring in the principal or longitudinal sections. COM means common species to other one or two sections; TAV, average of total number in sections; Number of species in the summer survey, except of the catch at a station unknown: *Gymnura japonica*.

	A			B			C			TAV
	SP	COM	TL	SP	COM	TL	SP	COM	TL	
P	1	14	15	9	15	21	13	7	20	18.3
E	3	9	12	4	10	14	11	7	18	14.7
A	4	7	11	7	7	14	8	3	11	12.0
TAV			12.7			16.3			16.3	

are the contrary. It is interesting that a remarkable difference may be recognized here between the Sections A and B, and the Section C. Comparing by the occurrence of special and common species, the latter surpass the other in the Sections A and B, but in the Section C is the contrary.

4. Frequency of occurrence of fishes to stations

The stations are found to be frequently occupied by certain species. (Table 6.) These are the *Callionymus lunatus*, which occurs in stations of 67.9% in average of surveys, *Rhinogobius pflaumi* (49.6–50.1%), *Chaeturichthys hexanema* (45.8%), and *Chaeturichthys sciistius* (44.5%). The *Limanda yokohamae* (11.8–13.2%) is the next, and the others occur in much lower percentages. As for the first four species, moreover, their occurrence is not partial, but extends more or less over stations and sections.

Table 6. Number of stations where some frequent fishes below are taken for season. %, percentage to the 53 stations for the average value of seasons. The following higher number or percentage means probable maximum value, when samples of unknown station is counted one by one as a catch of station new to survey concerned.

Species	P	E	A	%
Callionymus lunatus	42	34	32	67.9
Rhinogobius pflaumi	31	27–28	21	49.6–50.1
Chaeturichthys hexanema	25	31	17	45.8
Chaeturichthys sciistius	18	22	31	44.5
Limanda yokohamae	10	4–6	5	11.8–13.2

5. Number of individuals or catches in number

The most catches of 55 species sum up at most to several tens in number, and a group of fishes is always abundant to excel others remarkably in number. These mostly catched species of the surveys are counted to four: *Callionymus lunatus*, *Chaeturichthys hexanema*, *Chaeturichthys sciistius*, and *Rhinogobius pflaumi*, catches of which are totally 786, 674, 366 and 300 respectively, though some seasonal variation in their abundance.

6. Gravimetric abundances or catches in weight

The catches get to maximum at the spring survey, and the autumn catch is the minimum in weight. They are always measured as wet weight, of 11,472.1 gm., 10,651.3 gm. and 3,248.3 gm. in the spring, summer and autumn surveys respectively, and totally of 25,371.0 gm.

Of the 53 stations, the most catches of station are get in the Stations Nos. 49 and 92, where it is of 324.5–325.5 gm. in average of each season, while the least average catches in the stations Nos. 55 and 85, and it is of 7.0–9.7 gm.* (Fig. 3.)

* From this paragraph to the fifth, *Gymnura japonica* and *Lophiomus sentiferus* are neglected in descriptions.

The seasonal catches for station are in the bay as a whole 114.6 gm., 137.5 gm., and 61.3 gm. in average, in the spring, summer and autumn surveys respectively, and the seasonal average 104.0 gm. accordingly.

Fig. 3. Distribution maps of seasonal (A–C) and total (D) weight of catches in spring (A), summer (B) and autumn (C) surveys. Lengend common to A, B and C on upper left. The catches of 3,713.8 gm. is to be added to that of the summer survey (B).

These catches in each section are summarized in the Tables 7 and 8. In the latitudinal division, the Sections A (120.0 gm. in average) and B (97.4 gm.) appear to be more productive than the Section C (55.7 gm.) The Section E (134.0 gm. in average) of the longitudinal division and the Section M (124.1 gm.) of the vertical one do than the other (96.1 gm. and 95.8 gm. respectively.) As seen in the number of species for station (§ 2), the general trends are similar to these even in the Sections A and B classified in the subordinative sections, excepted the case of the Section B in summer.

Table 7. Average catches in wet weight (gm.) for station in the bay as a whole and the sections. 1) except of *Lophiomus setiferus* (St. No. 82, 5,400.0 gm.); 2) in any sections, except of catches at station unknown (3,713.8 gm.); 3) except of *Gymnura japonica* (St. unknown, 3,500.0 gm.)

	BAY	A	B	C	W	E	M	N
P	114.6[1)]	146.5	97.1[1)]	31.6	121.8[1)]	162.9	149.9	103.9[1)]
E[2)]	137.5[3)]	141.4	154.2	86.9	107.4	169.5	141.2	151.0
A	61.3	72.3	41.0	48.6	59.2	69.6	81.3	32.5
AV	104.0	120.0	97.4	55.7	96.1	134.0	124.1	95.8

Table 8. Average catches in wet weight (gm.) for station in the Sections A and B, belong to those of W, E, M and N.

	W		E		M		N	
	A	B	A	B	A	B	A	B
P	149.0	40.3	159.2	175.9	156.5	130.2	127.4	39.3
E	81.6	203.9	204.1	48.7	147.7	121.9	129.6	229.6
A	66.8	36.4	71.4	63.2	92.6	47.3	33.4	29.9
AV	99.1	93.5	144.9	95.9	132.3	99.3	96.8	99.6

Meanwhile, during the three surveys the catch in weight is seen to stand high above the other in some stations; these are the Stations Nos. 28 (Section A), 73 (Section B) and 89 (Section C) in the spring survey, the Stations Nos. 41, 49 (Section A), as well as Nos. 67, 81 (Section B), and 92 (Section C) in the Summer survey, and the Station No. 92 (Section C) in the autumn survey.

The supremacy is also recognized in catches for species. The prominent species in gravimetric catch are through the surveys called to five: *Lophiomus setiferus* (5,400.0 gm.), *Chaeturichthys hexanema* (4,204.2 gm.), *Callionymus lunatus* (3,975.4 gm.), *Gymnura japonica* (3,500.0 gm.), and *Limanda yokohamae* (2,225.6 gm.) Of these, the *Chaeturichthys hexanema* and *Callionymus lunatus* are already pointed out as dominant group species in individual number.

7. Zoogeographical status of the Tokyo Bay

a) Distributional range in the Japanese waters

Studying on about thousand marine fishes of Japan, TANAKA (1931) recognized

two ichthyofaunal areas, namely, southern and northern areas. He makes the boundary between these areas at the Cape of Inubo, near Choshi, Chiba Pref., on the Pacific coast, concerned herewith, where the fishes are classified to those ranging in distribution in southern (A), and northern (B) areas, and throughout Japan (C).

Classified as he does, our material is found to consist of 33 southern species, 20 species found throughout Japan, and two species of uncertain distributional range, one of which is to be of southern area or of throughout-the-land distribution. As far as our investigation goes, we agree well with Tanaka for the Tokyo Bay being mostly affected by warmer current.

b) Trophic composition of the catches

On the trophic level, the fishes are frequently given the three categories of plankton freeder, benthos eater, and fish predator, though it may be difficult to give precisely a definition on their feeding habit for species. (cf. HANAOKA 1953, SUYEHIRO 1942).

The catches then may be said at most benthos eaters; they are grouped into 6 species of plankton feeders, 41 species of benthos eaters, and 7 species of fish predators, with one species referable to no categories.

Their weight composition is totally of 61.2 gm., 15,956.9 gm. and 9,352.7 gm. respectively, or 0.24, 62.89, and 36.86% of the total weight. These percentages vary by seasons, and the highest value of each group is seen in summer, autumn, and spring surveys respectively (Table 9).

Table 9. Seasonal and total weight composition (gm., in light face) and its percentage (in bold face) for the trophic level of the catches. BE, benthos eater; FP, fish predator; PF, plankton feeder.

	PF		BE		FP	
P	2.54	**0.22**	5,983.1	**52.15**	5,463.6	**47.63**
E	30.1	**0.28**	6,815.0	**63.98**	3,806.2	**35.73**
A	5.7	**0.18**	3,158.8	**97.24**	82.9	**2.55**
TL	61.2	**0.24**	15,956.9	**62.89**	9,352.7	**36.86**

It is very interesting that the maximum value in each group occurs probably in order of their trophic level; high product of plankton feeders follows in summer to the spring outburst of the inferior consumers as zooplankton, and so forth.

It is also recognized that the autumn composition is apparently different from that of preceding seasons; the benthos eaters appear in remarkably high percentage, which occurs after the most prosperous season in the bay.

c) Sections and the faunal closeness coefficient

On the previous lines, some differences are pointed out in relation to sections given here. These differences take an apparent form by an ecological exponent, calculated from special and common species composition of the sectional catches. (Tables 10 and 11).

The faunal affinities among some regions or ecological habitat have been realized by some various exponents, and of these the Otuka's coefficient of closeness (p) is here applied, because it is said most reasonable, and indeed biogeo-

Table 10. Areal composition of the special and common species of the latitudinal sections, in the each season and through seasons, spring to autumn. Of the summer survey, excluded a catch at an unknown station: *Gymnura japonica*.

	SP			COM				TL
	A	B	C	ABC	AB	BC	AC	
P	1	6	13	6	8	1	—	35
E	3	4	11	4	4	2	1	29
A	4	7	8	1	5	1	1	27
P–A	2	10	23	11	6	2	—	54

Table 11. Areal composition of the special and common species of the longitudinal and vertical sections, for season and through seasons, spring to autumn.

	SP		COM	TL	SP		COM	TL
	W	E			M	N		
P	3	10	9	22	10	2	10	22
E	2	6	9	17	6	3	8	17
A	5	6	7	18	10	3	6	19
P–A	5	10	15	30	14	6	11	31

graphically effective.* (cf. OTUKA 1936, HAMAI 1955b.)

The values of p, seen in the Table 12, show that the affinity of the Sections A and B, as well as of the Section W and E, and the Sections M and N, is very closed, as compared with those of the Sections B and C, and A and C, and that in autumn the exponent in question shows a marked fall of value.

d) Interspecific relationships of quantity in catch composition

Supposing that the density, or number of individuals, of animals in a community are kept in an interspecific balance under certain conditions, and to explain the phase of community organisation, MOTOMURA (1932) proposes the law of geometrical progression.**

The sampling method may be discussed on its reliancy, while the law is said to have some reasonable stability. (SHINOZAKI and URATA 1953: 12.)

This law has been accepted to some studies on various plant and animal

* This exponent p is calculated as $c/\sqrt{S_1 S_2}$, where c is the number of common species between two regions concerned, and S_1 and S_2 are total number of species of these given regions.

** The low of geometrical progression is represented by the following formula: $\log y = b - a(x-1)$, a and b constant, where y means the density of a given species in an unit area, x, its ranking of the density, b, logarithm of the density of the dominant species in the given area, and a, an exponent of the intensity of competition. The common ratio, represented by e^{-a}, is regarded here as the coefficient of allowance, or maximum probability by which the species in question permits the other inferior ones in competition to exist together in the given area. (HAMAI 1955a: 172.)

Table 12. Coefficient of closeness between pairs of related sections, in each season and during seasons, spring to autumn. A×B, between Sections A and B, and so on.

	A×B	B×C	A×C	W×E	M×N
P	0.79	0.34	0.35	0.60	0.65
E	0.62	0.38	0.34	0.70	0.65
A	0.48	0.16	0.18	0.56	0.50
P–A	0.72	0.37	0.42	0.67	0.53

populations, though it remains some theoretical problems before used on ecological studies, and it appreciates as a practical law or an ecological measure. (cf. Yagi and Nomura 1953: 60; Miyaji and Mori 1955: v, 188; Numata and Yamai 1955: 168, foot note.)

It is orginally adopted to the number of individuals in a unit sample, and its reliability is more or less extended by authors. Yoshihara (1951), Hata-

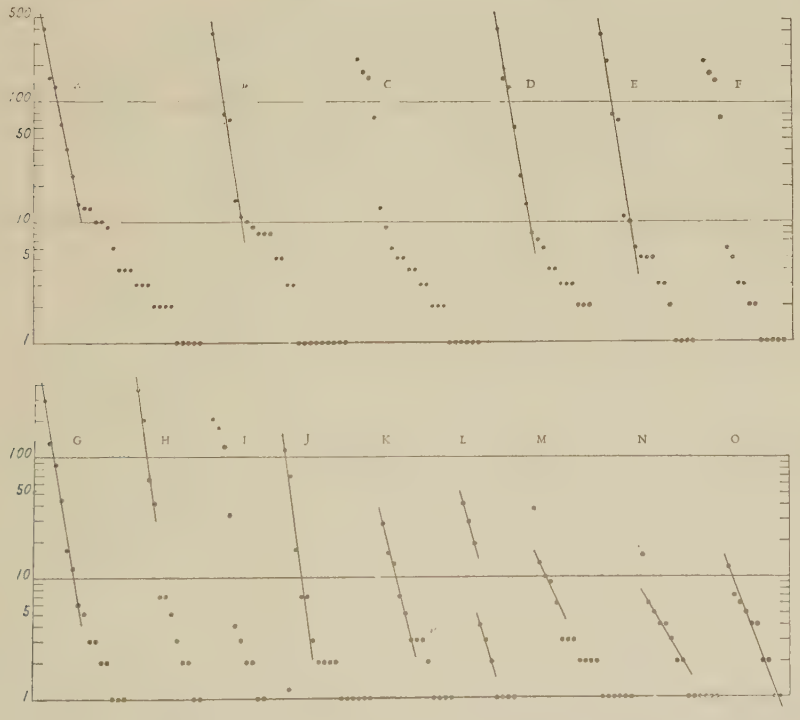

Fig. 4. Organisation diagram of the benthos eaters of the seasonal catches in the Tokyo Bay, represented by the number of individuals, based on the law of geometrical progression. A–C, the bay as a whole; D–F, the bay, *s. str.*; G–I, Section A; J–L, Section B; M–O, Section C; each of them arranged by seasonal sequence, spring to autumn. Abscissa, number of individuals; ordinate, sequence of abundances.

NAKA *et al.* (1954), and KINOE (1955) find it to be agreeably fitted in total or average density of trawler's catches, even if the number of individuals is replaced by the gravimetric density.

HATANAKA *et al.* (1954) pointed out in the benthic fish community, the law is not fitted in raw samples, but well in catches selected by their feeding habit.

As the greater number (74.5%) of our sample is the benthos eaters, as mentioned above, to these the law in question is examined here both in number of individuals and weight. (Figs. 4 and 5.)

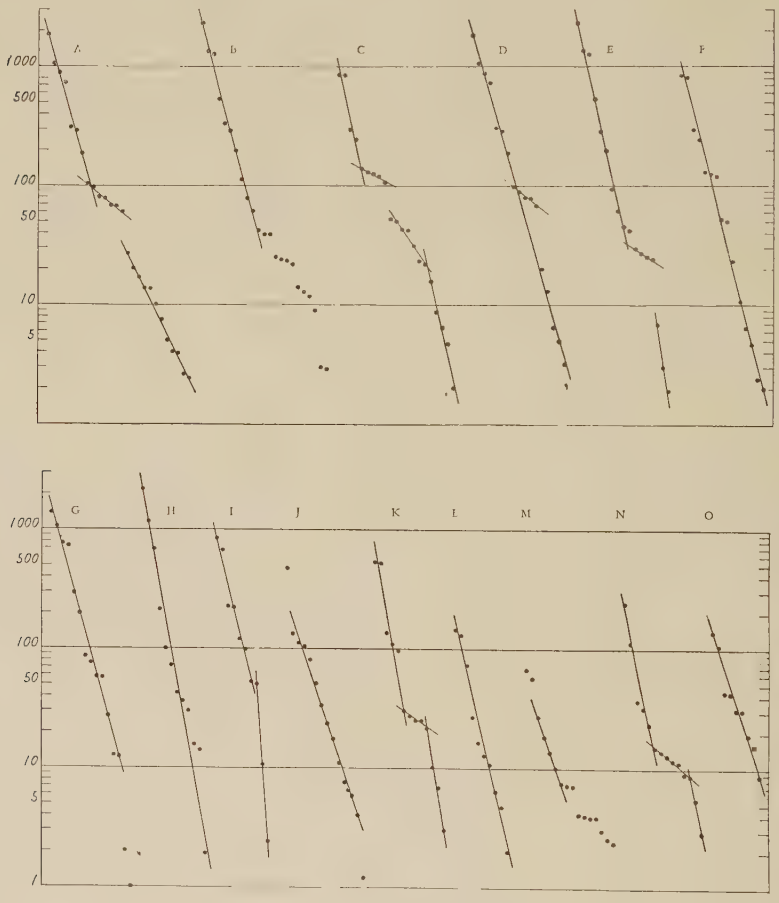

Fig. 5. Organisation diagram of the benthos eaters of the seasonal catches in the Tokyo Bay, represented by their weight (gm.), based on the law of geometrical progression. For letters, A–O, refer to Fig. 4. Abscissa, catches in weight (gm.); ordinate, sequence of abundances.

The fish community of the Tokyo Bay gives us at any rate some series of plotting lines on graphs, which say that, as far as my investigation goes, there are few groups of samples which may be concluded to be an organized community, or a group referable to one formurla, in spite of, according to the law of geo-

metrical progression, the community is to be represented as a whole by one formula in a considerably balanced biotope.

It is apparently recognized on these figures that the raws of plotted points fit to the law relatively well in gravimetric series rather than in numerical series. The former remains yet in itself some complexities, as pointed out by YOSHIHARA (1951: 701) and others.

As for the well fit populations, it seems that they happen almost in relation to no section nor season, except in case of the bay as a whole, when no fit group is composed. It remains to further investigations the reason why these irregularities come to pass.

8. Dominant group species

As seen in previous lines, the benthic fishes appear to be dominated in the Tokyo Bay by *Callionymus lunatus*, *Chaeturichthys hexanema*, *Chaeturichthys sciistius* and *Rhinogobius pflaumi*, of which the surveys reveal the facts below.

a) Total and seasonal fluctuations of abundance

In the bay as a whole, the total catch through seasons of *Callionymus lunatus* is 786 in number and 3975.4 gm. in weight, and of *Chaeturichthys hexanema*, *Chaeturichthys sciistius* and *Rhinogobius pflaumi* are 674 (4,204.2 gm.), 366 (406.8 gm.), and 300 (631.0 gm.) respectively.

In the spring survey the most catch is of *Callionymus lunatus* (407, 1,850.8 gm.), under which follow *Rhinogobius pflaumi* (156, 309.1 gm.), *Chaeturichthys hexanema* (131, 1,053.5 gm.), and *Chaeturichthys sciistius* (64, 102.3 gm.) In the summer survey, *Chaeturichthys hexanema* (367, 2,306.0 gm.) takes place of *Callionymus lunatus* (222, 1,271.4 gm.), which is in the next catch, and *Chaeturichthys sciistius* (78, 61.0 gm.) and *Rhinogobius pflaumi* (70, 196.7 gm.) follow them in order. In the autumn and last survey, *Chaeturichthys sciistius* (222, 243.5 gm.) is the dominant, and *Rhinogobius pflaumi* (74, 125.2 gm.) is in the lowest rank. The *Chaeturichthys hexanema* (176, 844.0 gm.) and *Callionymus lunatus* (167, 853.2 gm.) are between them in order.

These precedences may be said to hold among these fishes also in the Tokyo Bay *s. str.* (Sections A and B), while they vary more or less in each section. The catch of the Section C is out of discussion here because of its minority.

The total catches of the Section A are first 663 (4,001.6 gm.) of *Chaeturichthys hexanema*, 615 (3,189.6 gm.) of *Callionymus lunatus*, 314 (338.2 gm.) of *Chaeturichthys sciistius*, and 160 (392.6 gm.) of *Rhinogobius pflaumi*, while the dominant species in each season is the same as in the bay as a whole.

The seasonal catches are as follows: in the spring survey, *Callionymus lunatus* (291, 1,366.2 gm.) is the most, next *Chaeturichthys hexanema* (129, 1,036.0 gm.), *Rhinogobius pflaumi* (86,194.7 gm.) and *Chaeturichthys sciistius* (44, 75.0 gm.); in the summer survey, *Chaeturichthys hexanema* (358, 2,161.6 gm.) excedes *Callionymus lunatus* (202, 1,157.3 gm.) The *Chaeturichthys sciistius* (65, 36.0 gm.) and *Rhinogobius pflaumi* (41, 99.5 gm.) is the same in order as in the former survey; in the autumn survey, *Chaeturichthys sciistius* (205, 227.2 gm.), *Chaeturichthys hexanema* (176, 844.0 gm.), *Callionymus lunatus* (122, 666.1 gm.) and *Rhinogobius pflaumi* (33, 98.4 gm.)

In the Section B, it is noticeable that the total catch of *Chaeturichthys hexanema* (9, 153.9 gm.) comes nearly off the dominant group, and that *Rhinogobius pflaumi* (138, 234.2 gm.) competes with *Callionymus lunatus* (158, 718.4 gm.) in dominancy. The *Chaeturichthys sciistius* is 49 in number, and 64.7 gm. in weight.

Seasonally speaking, in the spring survey, *Callionymus lunatus* (113, 466.2 gm.), *Rhinogobius pflaumi* (69, 111.4 gm.) and *Chaeturichthys sciistius* (17, 23.4 gm.) keep in the dominant group, while *Chaeturichthys hexanema* (2, 17.5 gm.) is out of the group and fall in the sixth grade; in the summer survey, *Rhinogobius pflaumi* (28, 96.0 gm.) is the dominant, and *Chaeturichthys sciistius* (16, 25.0 gm.), *Callionymus lunatus* (13, 108.6 gm.) and *Chaeturichthys hexanema* (7, 136.4 gm.) in dorder; in the autumn survey, *Chaeturichthys hexanema* is not found anywhere, and *Rhinogobius pflaumi* (41, 26.8 gm.) holds its dominancy, and *Callionymus lunatus* (29, 143.6 gm.) and *Chaeturichthys sciistius* (19, 16.3 gm.)

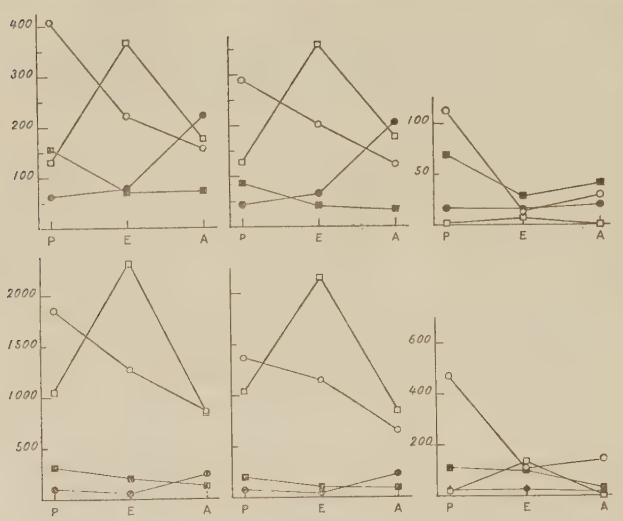

Fig. 6. Seasonal fluctuations of abundances of the dominant group fishes, *Callionymus lunatus* (○), *Chaeturichthys hexanema* (□), *Chaeturichthys sciistius* (●) and *Rhinogobius pflaumi* (■). Left, the bay as a whole; middle, Section A; right, Section B. Abscissa, number of individuals (upper) or catches in weight (gm., lower); ordinate, seasons: Spring (P), summer (E) and autumn (A).

Their abundances in surveys are summerized as in the following line. (Fig. 6.)

The fluctuations of their abundance in the bay may be said almost a copy of those in Section A, because the greater number of their total catches comes from the Section A. This is of 53.3–98.4% in number individuals, and 62.2–96.1% in weight.

These fluctuations in total catch are included to three types of the season. Those who have the season in spring are *Callionymus lunatus*, and *Rhinogobius pflaumi*. The *Chaeturichthys hexanema* is favorable in summer, and the best time of *Chaeturichthys sciistius* in the autumn. They are even the dominant of each season, except of *Rhinogobius pflaumi*, though the last one is gravimetrically inferior to *Callionymus lunatus* and *Chaeturichthys hexanema*, as well as *Rhinogobius pflaumi*.

As for the abundances for section, the fluctuations in the Section A are closely similar to those of the bay as a whole, while those of the Section B are rather different from that.

In the Section B, *Chaeturichthys hexanema* is so poor that its inhabitation is supposed to be restricted in the Section A, and *Callionymus lunatus* and *Chaeturichthys sciistius* as well, especially the former, seem to be weak in com-

parison with *Rhinogobius pflaumi*.

b) Seasonal densities on stations

The density may be precisely expressed by weight rather than by number of individuals, though as far as this investigation goes, both of them seems to show almost similar trends in general.

Generally speaking, there must be some densely populated areas of these fishes in the Tokyo Bay. They are frequently found to concentrate along the east coast of the bay, especially on its innermost region, and off northern coast of the Banzu Point, north of Kisarazu, Chiba Pref., as well as on the Nakanose, the conspicuous bank of the bay, in the Section B.

Callionymus lunatus: they are mostly found in spring at the offshore stations in the Section A, especially near the Station No. 49, and in the Section B near the bank, Nakanose. In summer they remove northward to stations

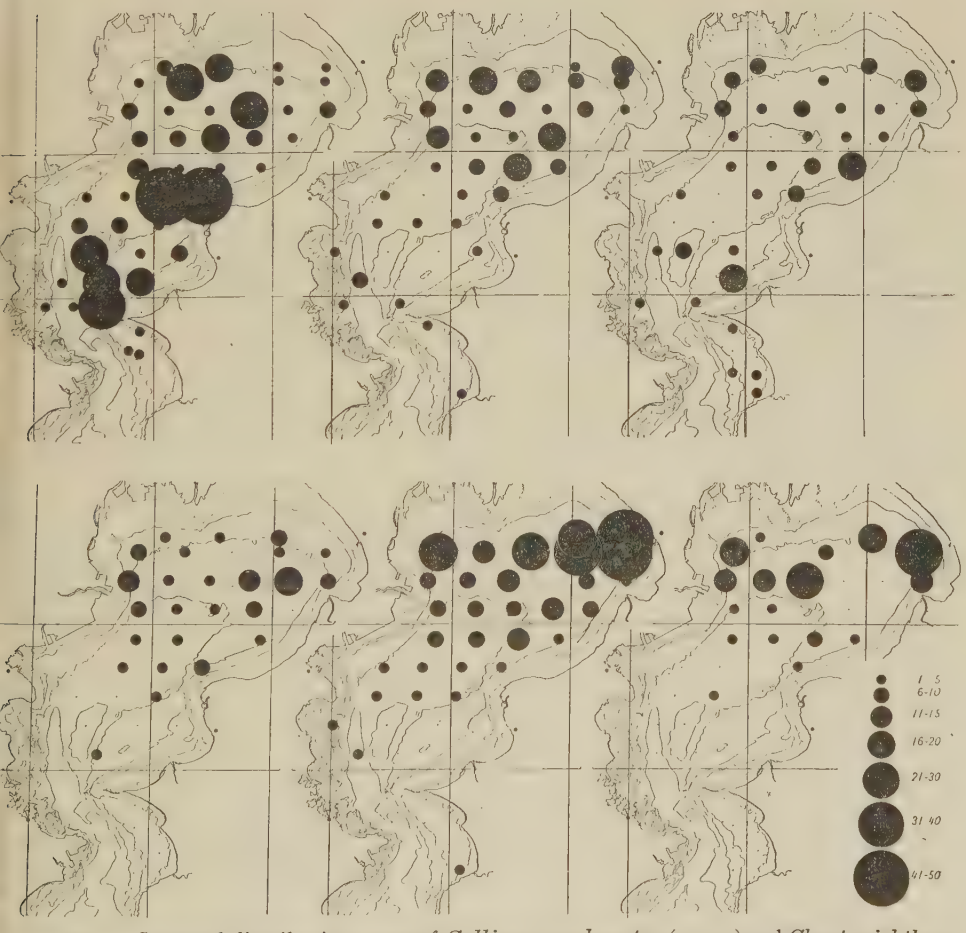

Fig. 7. Seasonal distribution maps of *Callionymus lunatus* (upper) and *Chaeturichthys hexanema* (lower), in terms of number of individuals as unit. Left, spring survey; middle, summer survey; right, autumn survey. Legend common to all.

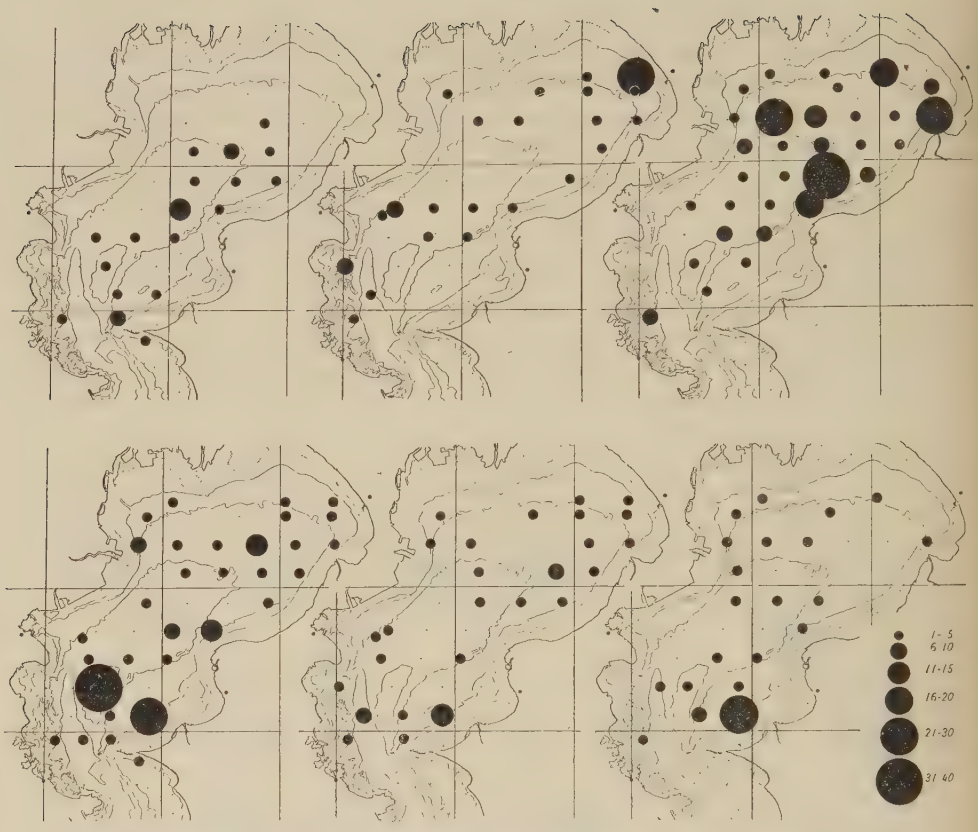

Fig. 8. Seasonal distribution maps of *Chaeturichthys sciistius* (upper) and *Rhinogobius pflaumi* (lower), by means of number of individuals as unit. For remarks and legend, refer to Fig. 7.

beyond the Banzu Point and the estuary of the Tama River, especially near the coastal areas. The fish in autumn is rather evenly distributed, but if remotely compared, they get together at the Stations Nos. 9, 28, 39 and 67. It seems interesting that these stations are in the closing areas in spring or summer surveys. (Figs. 7 and 9, upper.)

Chaeturichthys hexanema: the spring dense spots are found at the estuarine stations of the Tama River and rather offshore ones than the former, near eastward stations represented by No. 22. The fish closes in summer at the stations of wide range in eastern half of the Section A, especially near the Station No. 11. In autumn, they are remarkably poor, as already known, but the offshore stations of the Tama River, Nos. 24 and 26, and the eastern innermost ones around the station No. 9, may be recognizable as dense populated areas. (Figs. 7 and 9, lower.)

Chaeturichthys sciistius: no distinct dense area is found in spring and summer, while their distributions by the way is very various. They are in spring on eastern stations of rather limited areas, except of small number of

western stations. The stations of higher density are Nos. 33, 49, 61 and 80. In summer they are on a belt-like area of so-called Z-shape, where the fish is homogeneous except on the higher dense station No. 71. The autumn population occurs in wide range and get together distinctly on the Stations Nos. 3, 18, 26 and 41 in the densely populated areas above mentioned. (Figs. 8 and 10, upper.)

Rhinogobius pflaumi: it may be characteristic for this fish, and contrary to the above fish, that the densely populated areas are rather settled, and that the distribution range is broad, and not so various. It is also remarkable no fish is found through seasons on some areas, or at the Stations Nos. 5, 15, 51 and 63. In spring the fish is mostly found at the Stations Nos. 22, 47 and 73, in the eastern half of the bay, and on the Stations Nos. 17, 28 and 67, in the other half, especially on the southern stations in the Section B. The fish in summer

Fig. 9. Seasonal distribution maps of *Callionymus lunatus* (upper) *Chaeturichthys hexanema* (lower) in terms of weight (gm.) as unit. For remarks and legend, refer to Fig. 7.

Fig. 10. Seasonal distribution maps of *Chaeturichthys sciistius* (upper) and *Rhinogobius pflaumi* (lower) by weight (gm.) as unit. For remarks and legend, refer to Fig. 7.

Table 13. Size (or body length in mm.) composition of *Calliomymus lunatus*, female and male, in the bay as a whole and the Sections A and B, for season.

		♀ 0–25	25–50	50–75	75–100	100–125	125–150	♂ 0–25	25–50	50–75	75–100	100–125	125–150
	P		31	160	119				14	42	34	7	
BAY	E		5	100	72					6	38	1	
	A	7	14	46	50	1	1	2	4	2	15		2
	P		11	120	87				9	31	30	3	
A	E		3	95	64					3	36	1	
	A	2	11	44	43				3	2	14		
	P		20	39	31				5	10	4	4	
B	E			4	8					2	2		
	A	5	2	2	6	1		2	1		1		2

comes largely gather in two areas on the Stations Nos. 31 and 73. The autumn dense areas are not so distinguished, but it seems they remain on the Stations Nos. 3, 17, 28, 47, 57 and 73. (Figs. 8 and 10, lower.)

c) Areal size composition

The areal compositions of body length of these fishes are shown by their sex on the histogrammes in Figs. 11–14.

Callionymus lunatus of small size (0–25 mm. in length) appear during autumn survey especially in the Section B, and burst on spring in both Sections A and B in length of 50–75 mm. in mode. It is interesting that their sex ratio is remarkably low, especially in small size of body. (Table 13, Fig. 11.)

Chaeturichthys hexanema is very prosperous during summer, and in the Section A, as stated above. This group seems to be younger generation, 50–75 mm. of length in mode, to

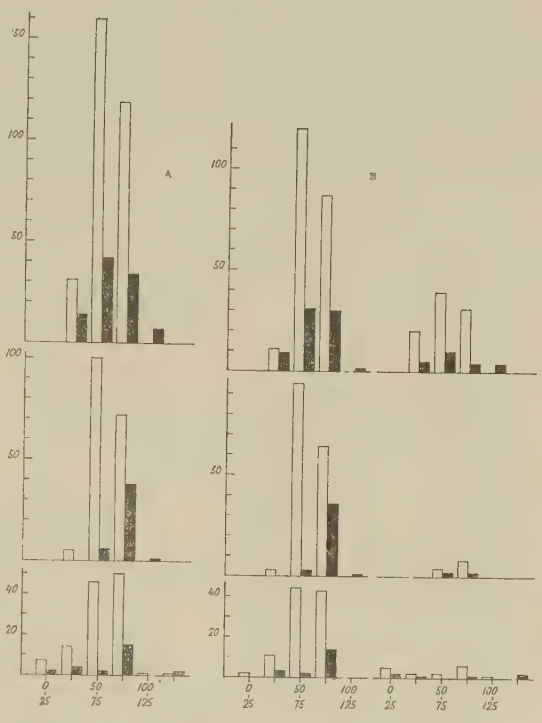

Fig. 11. Seasonal size frequency of *Callionymus lunatus* in the bay as a whole (A), and the Sections A (B, left) and B (B, right). Upper, spring survey; middle, summer survey; lower, autumn survey. White, female; black, male. Abscissa, number of individuals; ordinate, body length in mm.

Table 14. Size (b. l. in mm.) composition of *Chaeturichthys hexanema*, female and male, in the bay as a whole and the Sections A and B, for season.

		♀				♂				
		25–50	50–75	75–100	100–125	25–50	50–75	75–100	100–125	125–150
BAY	P	1	20	31	7		25	36	10	
	E	50	62	53	20	50	62	46	12	1
	A	8	77	12	2	6	57	15	1	
A	P	1	20	31	7		25	34	10	
	E	50	61	52	17	50	61	44	11	1
	A	8	77	12	2	6	57	15	1	
B	P							2		
	E			1	3			2	1	
	A									

the spring catches of 75–100 mm. of length in mode. The sex ratio is higher in spring, while it is lower in summer and autumn. (Table 14, Fig. 12.)

Chaeturichthys sciistius of younger forms 20–30 mm. of length in mode, appear in summer catch, which is apparently bimodal in size distribution, and generally speaking the smaller size group of the above length is in the Section A, while the larger size groups of 40–50 mm. of length in mode in the Section B. The sexual composition is similar to the above fish in trends. (Table 15, Fig. 13.)

Rhinogobius pflaumi of youngermost forms, 10–20 mm. of length in mode, appear first in the autumn catch. The size composition shows no bimodality, except in the Section B in summer, though this quality is not so conspicuous

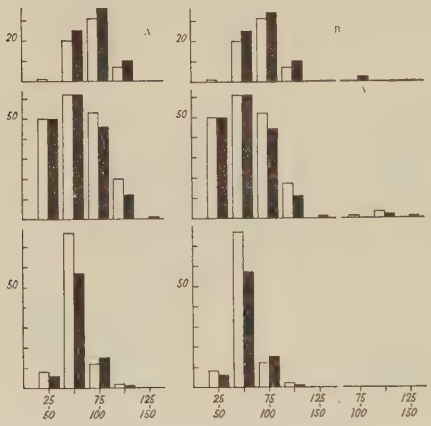

Fig. 12. Seasonal size frequency of *Chaeturichthys hexanema*. Refer to Fig. 11, for remarks.

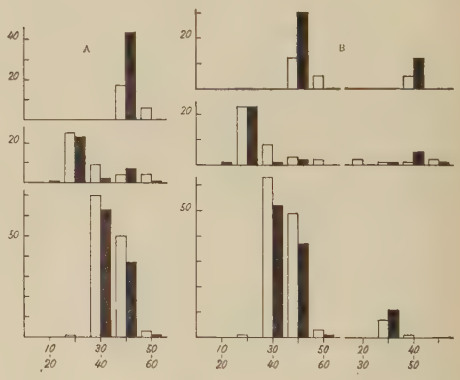

Fig. 13. Seasonal size frequency of *Chaeturichthys sciistius*. Refer to Fig. 11, for remarks.

Table 15. Size (b. l. in mm.) composition of *Chaeturichthys sciistius*, female and male, in the bay as a whole and the Sections A and B, for season.

		♀ 20–30	♀ 30–40	♀ 40–50	♀ 50–60	♂ 10–20	♂ 20–30	♂ 30–40	♂ 40–50	♂ 50–60
BAY	P			17	6				43	
	E	25	9	4	4	1	23	2	7	1
	A	1	70	50	3			63	37	1
A	P			12	5				30	
	E	23	8	3	2	1	23	1	2	
	A	1	63	49	3			52	37	1
B	P			5					12	
	E	2	1	1	2			1	5	1
	A		7	1				11		

Table 16. Size (b. 1. in mm.) composition of *Rhinogobius pflaumi*, female and male, in the bay as a whole and the Sections A and B, for season.

		♀ 10–20	20–30	30–40	40–50	50–60	60–70	70–80	♂ 10–20	20–30	30–40	40–50	50–60	60–70	70–80
BAY	P			17	30	30	5			2	18	29	21	2	
	E			1	16	14	3	1			2	8	12	5	1
	A	2	5	6	5	7	2		2	4	10	10	12	2	
A	P			6	13	22	5				8	15	14	1	
	E			1	9	12					1	5	11	2	
	A			2	2	7	2					6	12	2	
B	P			11	17	7				2	10	14	7	1	
	E				7	2	3	1			1	3	1	3	1
	A	2	5	4	3				2	4	10	4			

there. This fish is different to the others in relation to sexual composition. The sex ratio is lower in spring and summer, and higher in autumn. (Table 16, Fig. 14.)

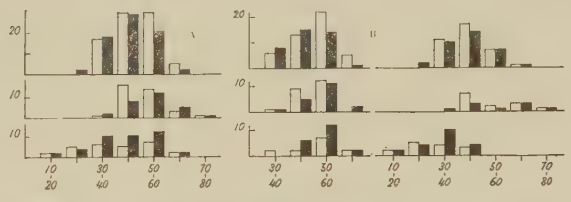

Fig. 14. Seasonal size frequency of *Rhinogobius pflaumi*. Refer to Fig. 11, for remarks.

After all, as for the size distributions in the whole bay sample, their general trends have some resemblances between *Callionymus lunatus* and *Rhinogobius pflaumi*, and between two species of *Chaeturichthys*.

Meanwhile the age composition seems rather simple in these species.

The sexual compositions take other trends on their affinities than the size distributions. The three types may be recognized here; remarkably low in all seasons in *Callionymus lunatus*, higher in spring in *Chaeturichthys* species, and higher in autumn in *Rhinogobius pflaumi*. It is interesting that in the bobiid fishes, the season of the higher sex ratio seems to precede apparently to their prosperous season.

Discussion

The bearing upon the fish population in the sea is apparently revealed by means of the hydrographical and biological conditions.

Of many physical and chemical conditions of the sea, the water currents seem to be particularly effective as a comprehensive form of them. According to Suda *et al.* (1931: 31), the water current of the Tokyo Bay consists as a rule of: inflowing current northeastwards along the east coast of the bay, outflowing one south- or southwestwards along the west coast, which make together the counter-clockwise current in the bay, and some eddies, or closed systems, found off

northern coast on the middle (surface) or eastern (—5 m. layer) area, and about the bank, Nakanose.

As for the biological conditions, which must be also influenced by the hydrographical ones, some studies have been published on the principal and epifaunas, as mentioned above, except of the crustacean contribution by KUBO and ASADA (1957), treating with the animal as the moving fauna.

According to MASUI (1943: 131–134), (1) the benthic faunal productivity is generally higher eastwards than westwards in the bay, and (2) in the northern half of about 10 m. depth in average, especially westward offshore region, it is lower than in deeper southern half of about 18 m. depth in average.

SHIMADZU and YAMANE (1948: 55) get a similar results, and says that eastern part of the region of A-type bottom temperature variation (or eastern A-type Section), C-type and E-type Sections are higher in the benthic productivities than the western A-type, B-type and D-type sections.

KITAMORI (1950: 226–227) points out that (1) the benthic fauna of the bay is remarkably changed in species at the limits of the Tokyo Bay, *s. str.*, and the Uraga Strait, and that (2) the eastern half of the bay is more abundant in species as well as in total weight of the benthos than the western half.

Recently KUBO and ASADA (1957: 289) gives the faunal scheme of the bay based on the benthic crustacean material, which says that (1) the faunal boundary should be settled on the limits of the Sections A and B, on many points of view, and here also that (2) the eastern half of the bay is more productive than its western half.

From these circumstances, it is apparently the inflowing and outflowing current that affect principally the benthic fauna in the Tokyo Bay (Tables 3 and 7). These currents must make and even resolve the ecological boundary of latitude.

It is another problem, however, why the eastern inflowing current seems to make the eastern half of the bay more abundant than the other, which may be answered by contamination of the city drainages on the western half of the bay, for instance, as pointed out by MASUI (1943: 131), KITAMORI (1950: 227), and KUBO and ASADA (1957: 287). Anyhow the qualitative or quantitative distribution of the benthic fishes must be in relation to the higher productivity in the eastern half region of their principal preys as the benthic polychaetes and crustaceans.

The benthic fish faunas are proved some remarkable changes at the limits of the Sections B and C (Tables 2 and 6). It fits in well with those of the principal faunas, but differs from the crustacean faunas included in the moving fauna.

The MASUI's second conclusion above mentioned appears in relation to the comparison between the productivities of the Sections A and B. The reversal result comes here probably because of the difference in fixation of the limits of the regions, or else in adaptation to their surroundings.

The other condition, eddies, has been proved to give usally an important influence to the distribution and abundances of the benthic fishes. (cf. TAIT 1952: 51.) Some eddies or else turbulences are observed here in addition to the principal forms above mentioned, and it is interesting that most of the higher

productive areas are found to correspond to those of the inflowing current. It is apparently the eddies around the bank, Nakanose, that causes the exceptionality of the Section B in summer in relation to the catches in weight, as stated above. (Tables 7 and 8, Fig. 3, B.)

These correspondencies appear to explain also the exceptional catches of some stations, as pointed out above.

It may be noticeable that the eastern corner of the Section A, off Shinagawa to Haneda, Tokyo, is frequently observed highly productive on the benthic fishes, contrary to the results of other animals. It remains to further investigations.

As for the seasonal fluctuation of lower animals as a biological condition in the Tokyo Bay, generally speaking, the polychaetes of the accessory fauna is most abundant in March to June and in November to January (Kitamori 1950), and the crustaceans of the moving fauna in spring (Kubo and Asada 1957). It seems the spring and summer abundances of the benthic fishes follow the autumn and spring prosperities of the inferior animals.

Summary

1) The demersal fishes collected by a small trawl net during spring to autumn 1954 in the Tokyo Bay are quantitatively studied.

2) They are totally 55 species belong to about 26 families, and of these the flat fishes (Pleuronectideans; 13 spp.) and the gobies (Gobiineans; 10 spp.) are remarkable.

3) Seasonally speaking, the number of species is generally larger in spring (35 spp.), and shows a gradual decrease to autumn (27 spp.) About half number of species occurs through seasons in common.

4) As for the number of species per station as well as per section, more or less remarkable variations are observed in seasons and sections. It shows generally seasonal decrease from spring to autumn, longitudinal difference between higher Section E and lower Section W, and latitudinal decrease from Sections A to C, or that of the reversal trend.

5) The gravimetric catch is totally of 25,371.0 gm. The catches per section give similar general trends in longitudinal difference and latitudinal decrease from Sections A to C, but the seasonal variation is different, where the higher value is seen in summer, and follow it those of spring and autumn.

6) According as the preceding works, our material is found to include 33 southern species and 20 ones throughout the land, and as for their trophic composition, mostly the benthos eaters (41 spp., 74.5%).

7) Referred to the Otuka's coefficient of closeness, the Section C is rather different in faunal composition with others which show some similar value of the exponent. This gives seasonally a marked fall of value in autumn.

8) Applied to the Motomura's law of geometrical progression, the demersal fishes on benthic prey represented by gravimetric catch are more or less better fitted in some seasons or sections, though they remain frequently some irregularities.

9) The dominant species of the benthic fishes in the Tokyo Bay are represented by the group of four species: *Callionyms lunatus*, *Chaeturichthys hexanema*, *Chaeturichthys sciistius*, and *Rhinogobius pflaumi*. Of these the fluctuation of abundance, seasonal distribution, and size and sexual composition are discussed.

10) The physical conditions as inflowing current or eddies, and the biological ones as their benthic prey of the inferior animals may be apparently concluded to affect to the abundance and distribution of the demersal fishes in the bay.

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ANNEXES

Tables 17–22, in the Pages 66–77.

Table 17. Specific catches in number of individual and numb
*, see text, p. 41. **, samples may be partly miss

Station No. / Species	*Calliomymus lunatus**	*Chaeturichthys hexanema*	*Chaeturichthys scistius*	*Rhinogobius flaumi*	*Urolophus aurantiacus*	*Hippocampus japonicus*	*Hippocampus* sp.	*Trachurus japonicus*	*Apogon lineatus*	*Apogon kiensis*	*Cilias pulchella*	*Enedrias nebulosus*	*Labricogobius exiguus*	*Rhinogobius gymnauchen*	*Acanthogobius flavimanus*	*Pterogobius zacalles*	*Sagamia geneionema*
1	3			1													
3	3	10		4													
5**	20	3															
6	8	2		1													
9	3	4		1										1			
11	2	1		1													
13																	
15	25	3															
17	2	9		5													
18	8	9		1													
20	1	16		1										4	2		
22	22	11	1	12													
24	1	5		1													
26	3	4		2													
28	7	12		9													
29	3			4										1			
31	10	6	3	4													
33	17	4	8	2													
35	9	3	1	1													
37	8	7															
39	1	2	1	4											1		
41	3		1														
43	2	1	3														
45	14	4		5													
47	47	7	1	11								1					
49	49	3	15	8					3							2	
51	3	1															
53	3														11		
55				1											3		
57	2	2	1	3													
59	6		5	1													
61	6		4	3													
63	6											2					
65	1					2	2		1						2		
67	26		2	35													
69															2		
71																	
73	18		1	22				1						1			
75	21	2	3	5												1	
77	3														3		
80	32		9	5					1								
81	3			1													
82	3		2	1													
83			3	1										6			1
84	1															27	2
85	1															3	2
86	1															3	4
87																	
88											1						
89										9	1		1				
90					1												
91																3	
92																1	1
Total	407	131	64	156	1	2	2	1	5	9	2	3	1	13	24	40	10

ollected species for station in the spring or first survey.
auling, but no modification is made in this study.

Hypodytes rubripinnis	*Omigocia spinosa*	*Platycephalus indicus*	*Chelidonichthys kumu*	*Radarius ercodes*	*Paraliichthys olivaceus*	*Pseudorhombus cinnamomeus*	*Engyprosopon grandisquama*	*Crossorhombus valderstratus*	*Pleuronichthys cornutus*	*Limanda yokohamae*	*Kareius bicoloratus*	*Heteromycteris japonicus*	*Areliscus interrupus*	*Hexagrammos otaki*	*Lophius litulon*	*Lophiomus setiferus*	No. of species
										1							2
																	4
																	2
														2			4
									1								5
																	3
																	0
										2							2
																	4
		1									1						3
																	7
																	4
																	3
									1	2				2			3
																	6
										1				1			3
																	6
										1							4
																	5
										1							2
													1				6
										1							3
																	3
										1							4
										2							6
																	6
																	2
																	2
		1								1							2
																	6
				1													3
									1					1	1		6
				1						2	1						10
																	8
																	5
									1				4				2
													2				6
						3							1			1	3
					1								1				6
																	5
																	4
																	3
																	3
5																	0
8	3		2	1			1	1									2
																	10
													1				1
				1								2					2
																	4
3	3	2	2	4	1	3	1	1	4	14	2	2	10	6	1	1	—

Table 18. Specific and total catches in weight (gm.) for stat

Station No. \ Species	*Calliomymus lunatus**	*Chaeturichthys hexanema*	*Chaeturichthys scistius*	*Rhinogobius pflaumi*	*Urolophus aurantiacus*	*Hippocampus japonicus*	*Hippocampus* sp.	*Trachurus japonicus*	*Apogon lineatus*	*Apogon kinensis*	*Cilias pulchella*	*Enedrias nebulosus*	*Lubricogobius exiguus*	*Rhinogobius gymnauchen*	*Acanthogobius flavimanus*	*Pterogobius zacalles*
1	9.0			2.5												
3	14.2	55.6		10.5												
5**	65.5	20.8														
6	32.6	8.1		0.9												
9	12.9	33.0		1.9										2.1		
11	5.6	5.3		3.3												
13																
15	98.8	27.8														
17	13.8	53.7		10.1												
18	22.5	49.8		2.3												
20	8.2	93.6		4.4										9.8	10.4	
22	74.8	105.2	1.5	28.7												
24	6.9	66.9		2.0												
26	17.3	44.3		5.6												
28	45.3	95.1		23.9												
29	8.4			7.7										0.4		
31	56.6	64.1	5.4	9.4												
33	124.4	38.8	14.5	1.7												
35	54.6	25.8	1.5	0.8												
37	43.0	53.7														
39	7.6	18.6	1.3	12.9											1.3	
41	16.5		1.9													
43	10.8	12.8	4.5													
45	81.1	30.3		7.4												
47	104.1	69.2	1.4	29.1								1.0				
49	310.2	30.1	23.3	8.9					12.6							2.0
51	15.9	14.8														
53	17.7														31.8	
55				1.2											13.5	
57	12.5	18.6	1.4	9.5												
59	35.0		8.7	1.1												
61	40.4		9.6	8.9												
63	23.0											4.0				
65	1.4					1.4	0.6		3.8						1.6	
67	86.8		2.4	68.0												
69															3.5	
71																
73	55.0		1.2	33.1				1.9						0.7		
75	115.0	17.5	3.8	3.8												1.2
77	11.9														5.9	
80	126.0		13.6	4.7					3.8							
81	16.9			0.8												
82	30.2		2.4	1.0												
83			3.9	3.0										4.1		
84	13.3															44.7
85	2.7															3.2
86	2.4															5.2
87																
88											5.3					
89										27.0	16.2		0.5			
90					54.5											
91																2.5
92																1.2
Total	1850.8	1053.5	102.3	309.1	54.5	1.4	0.6	1.9	20.2	27.0	21.5	5.0	0.5	17.1	68.0	60.0

ıe spring or first survey. *, **, refer to remarks of Table 17.

Hypodytes rubripinnis	*Onigocia spinosa*	*Platycephalus indicus*	*Cheilodactylus kumu*	*Rudarius ercodes*	*Paralichthys olivaceus*	*Pseudorhombus cinnamoneus*	*Engyprosopon grandisquama*	*Crossorhombus valderstratus*	*Pleuronichthys cornutus*	*Limanda yokohamae*	*Kareius bicoloratus*	*Heteromycteris japonicus*	*Arelisceus interrupus*	*Hexagrammos otaki*	*Lophius litulon*	*Lophiomus setiferus*	Total
										35.1							11.5
																	115.4
																	86.3
														331.4			373.0
									9.2								59.1
																	14.2
																	0
																	126.6
										121.2							198.8
																	74.6
		128.5									85.3						340.2
																	210.2
																	75.8
																	67.2
									17.8	100.9				375.0			658.0
																	16.5
										49.4				15.7			200.6
																	179.4
										35.4							118.1
																	96.7
													56.7				98.4
										81.7							100.1
																	28.1
										23.7							142.5
										75.7							280.5
																	387.1
																	30.7
																	49.5
																	14.7
		161.5								227.0							430.5
																	44.8
																	58.9
				3.4													30.4
																	8.8
									4.4					5.8	9.1		176.5
																	3.5
																	0
				3.1						132.6	103.9						331.5
																	141.3
																	17.8
									46.4				28.2				222.7
													4.5				22.2
						79.5							0.7			5400.0	5513.8
													1.9				14.0
					4.0												64.3
																	9.0
																	13.6
																	0
24.5																	29.8
42.0	10.1		3.9	2.8			2.6	2.4									108.4
													5.2				54.5
																	7.7
				4.4								7.5					14.3
66.5	10.1	290.0	3.9	13.7	4.0	79.5	2.6	2.4	77.8	882.7	189.2	7.5	97.2	727.9	9.1	5400.0	11472.1

Table 19. Specific catches in number of individuals and number of collected

Station No. \ Species	*Calliomymus lunatus**	*Chaeturichths hexanema*	*Chaeturichthys sciistius*	*Rhinogobius pflaumi*	*Dasyatis akajei*	*Gymnura japonicus*	*Fistularia villosa*	*Hippocampus japonicus*	*Upeneus bensasi*	*Apogon lineatus*	*Epinephelus septemfasciatus*	*Johnius belengeri*	*Cilias pulchella*	*Enedrias nebulosus*	*Acanthogobius flavimanus*
1	15	55	21	2											
3	3	26	4	3											1
5															
6															
9	10	56	4	1											
11	9	32	2	2											1
13	14	21	3	3											
15	16	12													
17	14	22	1	2											
18	1	4	1	2											
20	7	9	3	1											
22	2														
24	7	11	3												
26	5	8	1	2											
28	7	8		2											1
29		8	2	1											
31	19	13		8											
33	1	8													
35	5	6		1											
37	12	6													
39	6	5	1	1											
41	20	13		1											
43	8	9		1						1					
45	4	8								1					
47	6	4	1												
49	2	4	4												
51		1	1												
53	3	5	7	1											
55			2	3											
57	2	2	3	2											
59	1	1	1												
61	3	1		2											
63	1							1							
65										1				2	
67															
71	5	3	10	1										1	
73				15				1							
75				1											
77	7	4	2	6											
80	2			2											
81															
82	1		1	3						2					
83	1														
84															
85										1					
86										1					
87							1								
88									1				1		
89															
90										1	1				
91															
92	3	2			2					1		5			
unknown				1		1									
Total	222	367	78	70	2	1	1	2	1	9	1	5	1	3	3

species for station in the summer or second survey. *, see text, p. 41.

Pterogobius zacalles	*Sagamia geneionema*	*Halicocrus poecilopterus*	*Sebastiscus marmoratus*	*Stephanolepis cirrhifer*	*Rudarius ercodes*	*Lactoria diaphanus*	*Paralichthys olivaceus*	*Engyprosopon ui*	*Pleuronichthys cornutus*	*Limanda yokohamae*	*Kareius bicoloratus*	*Zebrias zebra*	*Rhinoplagusia japonica*	*Arelisicus interrupus*	No. of species
															4
															5
															0
															0
															4
															5
															4
															2
															4
															4
															4
											1				1
															4
															4
															4
															3
															3
															2
															3
															2
									3						5
									2	1					5
															4
															3
															3
2	1								1	5				5	8
															2
															4
															2
															4
									1	1					5
				2											3
															3
										1					2
															1
				3	2										5
															4
															1
															4
														1	3
							1								1
3			1			1									6
															2
															0
															1
															1
	1			1	1										4
								1							3
															0
	7			1	1										5
	6	1		1	4							1	1	2	4 8 —
									3	3					
5	15	1	1	8	8	1	1	1	10	11	1	1	1	8	—

Table 20. Specific and total catches in weight (gm.)

Station No. / Species	*Callionymus lunatus**	*Chaeturichthys hexanema*	*Chaeturichthys scistius*	*Rhinogobius pflaumi*	*Dasyatis akajei*	*Gymnura japonica*	*Fistularia villosa*	*Hippocampus japonicus*	*Upeneus bensasi*	*Apogon lineatus*	*Epinephelus septemfasciatus*	*Johnius belengeri*	*Cilias pulchella*	*Enedrias nebulosus*	*Acanthogobius flavimanus*
1	83.9	83.6	6.5	2.8											
3	13.5	101.1	1.3	8.9											11.9
5															
6															
9	42.6	129.7	1.2	3.1											
11	59.6	208.2	0.7	3.5											9.6
13	79.5	103.8	1.5	6.7											
15	69.7	31.5													
17	66.1	68.5	0.3	5.7											
18	5.3	37.2	0.4	3.0											
20	44.1	77.7	1.1	3.0											
22	8.9														
24	49.1	74.0	1.1												
26	25.1	66.4	0.4	4.0											
28	44.4	25.6		7.5											8.1
29		70.8	0.6	2.5											
31	90.1	169.6		20.5											
33	4.5	102.0													
35	32.5	52.6		3.8											
37	70.3	37.9													
39	49.9	72.7	2.2	3.1											
41	121.2	182.9		2.7											
43	52.8	117.1		1.6						8.0					
45	29.4	92.7								7.6					
47	42.7	70.2	0.5												
49	14.8	38.9	9.6												
51		18.0	1.7												
53	15.8	33.1	2.9	1.3											
55			0.5	5.7											
57	11.9	46.1	1.3	6.3											
59	8.7	25.0	2.2												
61	20.9	24.7		3.8											
63	9.1							0.8							
65										17.8					
67														17.3	
71	39.2	66.3	21.4	1.9											
73				78.5				1.6						8.0	
75				1.7											
77	44.3	70.1	0.7	8.0											
80	11.0			3.2											
81															
82	5.0		2.9	2.7						12.0					
83	0.8														
84															
85										7.1					
86										7.4					
87							6.8								
88									11.8				20.9		
89															
90										5.9	0.2				
91															
92	4.7	8.7			306.0					11.7		14.0			
unknown				1.2		3500.0									
Total	1271.4	2306.7	61.0	196.7	306.0	3500.0	6.8	2.4	11.8	77.5	0.2	14.0	20.9	25.3	29.6

for station in the summer or second survey. *, see text, p. 41.

Pterogobius zacalles	*Sagamia geneionema*	*Halicoerus poecilopterus*	*Sebastiscus marmoratus*	*Stephanolepis cirrhifer*	*Rudarius ercodes*	*Lactoria diaphanus*	*Paralichthys olivaceus*	*Engyprosopon ui*	*Pleuronichthys cornutus*	*Limanda yokohamae*	*Karenus bicoloratus*	*Zebrias zebra*	*Rhinoplagusia japonica*	*Arelescus interrupus*	Total
															176.8
															136.7
															0
															0
															176.6
															281.6
															191.5
															101.2
															140.6
															45.9
															125.9
															8.9
											42.1				166.3
															95.9
															85.6
															73.9
															280.2
															106.5
															88.9
															108.2
									74.5						202.4
									65.2	219.1					591.1
															179.5
															129.7
															113.4
14.0	1.9								22.7	403.8				72.2	577.9
															19.7
															53.1
															6.2
															65.6
									51.0	60.1					147.0
															49.4
				7.2											17.1
															35.1
										520.0					520.0
															136.8
				20.1	6.8										107.0
															1.7
															123.1
														21.5	35.7
							530.0								530.0
10.2			3.0												35.8
						2.9									3.7
															0
															7.1
															7.4
	2.2			4.8	3.8										17.6
								9.0							41.7
															0
	23.9			1.0	0.8										31.8
	10.6	23.5		5.5	10.4										50.0
												12.9	112.3	239.4	709.7
									72.7	139.9					3713.8
24.2	38.6	23.5	3.0	38.6	21.8	2.9	530.0	9.0	286.1	1342.9	42.1	12.9	112.3	333.1	10651.3

Table 21. Specific catches in number of individuals and number of collect

Station No. / Species	*Callionymus lunatus**	*Chaeturichthys hexanema*	*Chaeturichthys scistius*	*Rhinogobius pflaumi*	*Trachinocephalus myops*	*Syngnathus schlegeli*	*Hippocampus japonicus*	*Apogon lineatus*	*Epinephelus septemfasciatus*	*Acanthogobius flavimanus*	*Pterogobius zacalles*	*Sagamia geneionema*	*Tridentiger trigonocephalus*
1													
3	10	20	18	4									
5			1										
6	7	3	3	2						1			
9	12	36	7							1			
11													
13	5	10	4	2									
15													
17	7	18	2	4									
18	6	12	23	1									
20	3		2										
22	1		1										
24	9	23	12	1						1			
26	4	15	23	1									
28	10	15	3	4									
29	1		1										
31	2		1										
33	4		7					2	1				
35		2	2										
37	4	4	8	1									
39	16	2	9										
41	7	6	39	2									
43	2	1	2	1									
45	2	5	2	1									
47	7	3	16	5									
49	1		1										
51			1										
53	2		4										
55													
57			7	3									
59		1	6	1									
61													
63									1				
65	2		4	2		1							
67	8		5	1									
69	1			2									
71													
73	16			25		1	2	2					
75			4	6									
77													
80	1						4	2					
81													
82	1		6	5							1	2	1
83													
84													
85	2												
86					1								
87	1											3	
88												1	
89					2								
90												2	
91	2												
92	1											1	
Total	157	176	224	74	3	2	6	6	2	3	1	9	1

cies for station in the autumn or last survey. *, see text, p. 41.

Hypodytes rubripinnis	Suggrunculus meerdervoorti	Rudarius ercodes	Paralichthys olivaceus	Tarphops oligolepis	Engyprosopon grandisquama	Pleuronichthys cornutus	Limanda yokohamae	Kareius bicoloratus	Heteromycteris japonicus	Rhinoplagusia japonica	Arelisicus interrupus	sp. unknown	No. of species
													0
													4
													1
													5
													4
													0
													4
													0
													4
													4
													2
													2
							1	1					7
		1											4
													5
													2
1													2
													5
													2
													4
1							1						4
													5
													4
													4
													4
													2
													1
													2
													0
													2
							1						4
							1						1
						1							1
													5
						1							3
													0
						1	1					4	8
											1		3
													0
												1	4
													0
													6
													0
		9											1
				1									2
				1	3				1				4
		2	1		1				1				6
									1				1
													2
	2	1			1				1				1
1			1	2						1			5
													6
1	2	13	2	4	5	3	5	1	4	1	1	5	—

Table 22. Specific and total catches in weight (gm.) f

Station No. / Species	*Callionymus lunatus**	*Chaeturichthys hexanema*	*Chaeturichthys scistius*	*Rhinogobius flaumi*	*Trachinocephalus myops*	*Sygnathus schlegeli*	*Hippocampus japonicus*	*Apogon lineatus*	*Epinephelus septemfasciatus*	*Acanthogobius flavimanus*	*Pterogobius zacalles*	*Sagamia geneiomema*	*Trigentiger trigonocephalus*
1													
3	48.4	88.6	21.9	11.6									
5			1.2										
6	36.2	11.6	3.2	6.3						6.2			
9	74.1	150.4	7.1							6.9			
11													
13	34.4	41.2	2.7	5.1									
15													
17	46.9	49.2	2.3	9.7									
18	27.7	60.9	35.2	3.3									
20	0.8		1.0										
22	5.2		1.2										
24	45.5	92.2	12.2	2.9						36.9			
26	21.6	69.7	30.9	5.3									
28	50.0	48.4	3.4	15.2									
29	0.2		0.8										
31	20.1		1.6										
33	18.4		6.5					10.4	19.1				
35		19.1	2.8										
37	30.5	24.9	8.0	0.6									
39	95.5	12.8	6.6										
41	34.4	44.4	35.2	5.2									
43	7.3	15.8	2.4	4.7									
45	14.0	42.8	2.5	3.1									
47	33.3	46.3	19.0	12.2									
49	7.3		1.2										
51			1.1										
53	14.3		4.2										
55													
57			7.3	10.0									
59		25.7	5.7	3.2									
61													
63									17.6				
65	15.8		3.2	2.2		2.2							
67	54.9		5.3	2.3									
69	28.7			2.3									
71													
73	2.8			10.9		0.8	0.7	2.0					
75			3.6	5.8									
77													
80	41.2						2.0	10.8					
81													
82	0.2		4.2	3.3									
83											4.7	10.7	2.0
84													
85	8.7												
86					20.7								
87	32.7												
88												10.4	
89					25.5							5.6	
90													
91	1.5											11.3	
92	0.6											4.2	
Total	853.2	844.0	243.5	125.2	46.2	3.0	2.7	23.2	36.7	50.0	4.7	42.2	2.0

on in the autumn or last survey. *, see text, p. 41.

Hypodytes rubripinnis	*Suggrunculus meerdervoorti*	*Rudarius ercodes*	*Paraliichthys olivaceus*	*Tarphops oligolepis*	*Engyprosopon grandisquama*	*Pleuronichthys cornutus*	*Limanda yokohamae*	*Kareius bicoloratus*	*Heteromycteris japonicus*	*Rhinoplagusia japonica*	*Areliscus interrupus*	sp. unknown	Total
													0
													170.5
													1.2
													63.5
													238.5
													0
													83.4
													0
													108.1
													127.1
													1.8
													6.4
							79.2	52.5					321.4
													127.5
		2.4											119.4
													1.0
													21.7
.6													146.0
													21.9
													64.0
							33.5						148.4
.7													147.9
													30.2
													62.4
													110.8
													8.5
													1.1
													18.5
													0
													17.3
							46.3						80.9
							62.6						62.6
													17.6
						32.9							56.3
													62.5
						63.3							94.3
													0
						34.0	72.9					0.6	124.7
											6.4		15.8
													0
												0.3	54.3
													0
													25.1
													0
		7.4											7.4
				4.4									13.1
				8.3	23.9				14.7				67.6
		11.5	2.3		3.0				5.6				65.5
													5.6
									19.4				44.9
													11.3
	8.7	0.5			3.9				3.2				17.8
0.4			104.9	3.1						139.3			252.5
3 0.4	8.7	21.8	107.2	15.8	30.8	130.2	294.5	52.5	42.9	139.3	6.4	0.9	3248.3

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STUDIES ON THE FAT METABOLISM OF FISH
2. HISTOLOGICAL AND CHEMICAL STUDIES ON FAT AND PHOSPHORUS IN RAINBOW TROUT

Toyoki Ono, Jirō Senō, Fumio Nagayama and Kazuaki Hikota

(Received Sep. 20, 1958)

In a preceding paper, it was shown that the fat content of carp muscle increases corresponding to the growth of fish, but phosphorus makes its content to a decrease in response to the fattening of fish after a certain larval stage at which the phosphorus content reached to the maximum value[14].

From these results we supposed that the phosphorus will be mainly utilized for the energy formation from fatty substances in tissue and for performing a physiological function such as cellular respiration.

The pathway of phosphorus in fat metabolism have been studied concerning with the coenzymes containing phosphorus or the ATP which accelerates the enzymatic oxidation of fatty acids in animal tissues[1,2,3]. Phosphatides are known as a source of choline, a useful factor in the nervous system, a promotor on the coagulation of blood, and to have the control actions of permeability and the reducto-oxidation of living cell concerning also with the fat metabolism including absorption and transportation of fatty acids[4], and they are thought as an intermediate products in fat metabolism[5].

They are, moreover, known as the substance to be transported to an ovary through the blood flowing from liver in which they are synthesized[6], and Sinclair[7] reported that the phosphatides, in his experiments using rat, indicated the highest content at the birth, but it decreased to a half in three months later. Artom[8] proved that the phosphatide is accumulated in liver, kidney and intestine in an animal fed with a fatty feed and is an important factor on fat metabolism.

It is, moreover, interesting that the purified ATPase which contained a considerable amount of phosphatide was inactivated by the hydrolysis with an esterase, phospholipase D[9,10].

In preceding paper we demonstrated that the histological observations on the distribution of fat in carp muscles agree with the chemical analysis[14]. In this experiment, we attempted to explain the histological changes during the development and growth with rainbow trout. However, the results must be confirmed by chemical methods. We intended to observe the pathway of fat formation and the role and behavior of phosphorus in rainbow trout referring to some recent studies carried on same fish[11,12,13].

We wish to express our thanks to Prof. Denzaburō Inaba and Mr. Zenjirō Uematsu for kind supply of samples, and to Mr. Kenjirō Konno for his painstaking effort to take many microscopic photographs.

Experimental

1. Materials

The unfertilized eggs were collected from a four years rainbow trout, *Salmo irideus* (G.), adulted in an experimental pond at Ōizumi, and the egg grew into an adult fish passing through the following stages; fertilized egg, eyed egg, sac fry (hatching), unfed fry, fingerling and yearling.

Sample taken in each stage was freezed with dry ice or reserved in formalin solution and analysed immediately after the transportation to our laboratory. Unfertilized and fertilized eggs were used a whole body as sample, but the samples of eyed egg and hatching stages were separated into two parts, embryo and yolk, and then the samples in subsequent stages into three parts, muscle, viscera, and the others containing bone, head, and skin. Details in sampling were shown in Table 1.

Table 1. Details of sampling of rainbow trout.

Stage no.	Date of Sampling	Stage of sample	Numbers of analysed sample	Average weight (g.)	Average length (cm.)	No. of figure in plate
I	March 2, 1953	Unfertilized egg	70	0.088		1
II	March 9	Fertilized egg	70	0.114		2
III	March 22	Eyed egg	70	0.111		3
IV	April 4	Sac fry (hatching)	70	0.099		4,25,26
V	April 19	Sac fry	50	0.132	0.20	5,27
VI	April 28	Unfed fry (yolk sac is absorbed)	30	0.163	0.23	6,7,28
VII	May 3	Fingerling (feeding is started)	15	0.250	0.27	8
VIII	June 2	Fingerling	10	0.675	0.30	9
IX	July 2		10	1.25	0.37	10,11
X	July 30		7	2.65	4.95	12
XI	Nov. 2		5	5.42	6.57	13,14
XII	April 10, 1954	Yearling	3	110	18.5	15~24

2. Histological method

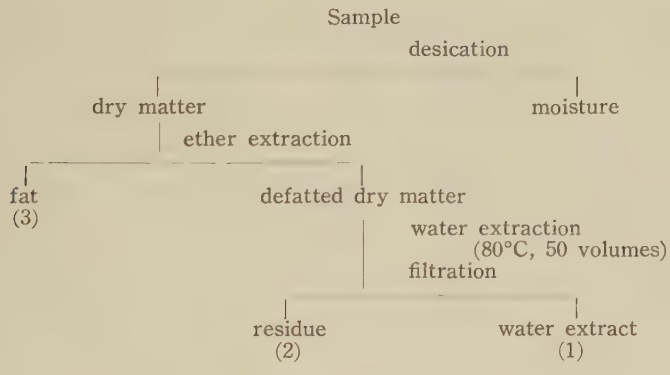
As a histological method was used a procedure of Baker[16].

1). Tissue was fixed for 3 days in 10% formalin cotaining 1% $CaCl_2$.
2). After washing for 4 hours in runing water, it was infiltrated in 25% gelatin solution for 1 day at 37°C.
3). After cooling it was cut out block and hardened for more than 24 hours in a cadmium-calcium formalin solution.
4). It was washed again for 4 hours in runing water and cooled with dry ice, then sectioned in 30–60 microns on the freezing microtome.
5). Floated sections on water in a large Petri dish was shifted onto a slide absorbing remained water with blotting paper.

6). 2.5% gelatin solution was dripped on the section in order to float it on the coated face of the slide.
7). After leaving the section for 10 minutes at normal temperature and wiping off the excess gelatin, the section was fixed for 10 minutes face down in a strong formalin solution.
8). Sections were stored in staining jars in Cd-Ca-formalin solution.
9). They were washed for 3 minutes in running water, then after treating with 50 and 70% alcohol for 1–2 min. each, stained in a saturated alcoholic solution of Sudan III.
10). Stained sections were rinsed in three 30-second changes of 50% alcohol and finally in distilled water.
11). They were mounted in glycerin.

3. Analytical method

Phosphorus was estimated by TISDALL's method[15] being fractionated into 3 types; water soluble-P, water insoluble-P, and ether soluble-P. The scheme for fractionation is outlined in Text-fig. 1.



Text-fig. 1. Scheme of analyses for phosphorus
1, water soluble phosphorus: 2, water insoluble phosphorus: 3, ether soluble phosphorus.

Results

Histological observations

Notwithstanding a fairly amount of microscopic photographs of histological preparations, 55 in total, merely a half of them has been shown in this report. Fat droplets mainly deposit at animal pole in a mature unfertilized egg (Fig. 1) and it seems that they unite gradually themselves in the neighborhood of the egg membrane being absorbed and assimilated as the result of embryo formation (Figs. 2 and 3). It is already clear in an eyed egg that the deposition of fat is absorbed and transferred into the embryo, namely it was stained in orange tint in the tissue of dark muscle and of other parts (Fig. 3). Fat storage in an egg does not almost find at the time of hatching, that is as shown in figures 4 and 25, a large mass of fat and its erosions in yolk are recognisable.

The fat content of muscular tissue increased rapidly making the following regions, in the myotomes, under the dorsal fin and near the dark muscle, as a center (Fig. 5). In a hatched larva, viscera, spinal cord, Musculus levator vel erector radiorum pinnae dorsalis and M. flexor vel erector radiorum pinnae dorsalis have already been formed. The increase of fat content is observed in the portions mentioned above, that is in and near the spinal cord, inter and intra muscular spaces and around the dark muscle. Contrary to the increase of fat content, an enormous decrease in the yolk storage is observed (Figs. 5～7 and 24～26).

Although yolk absorption in a 25 day old fish after hatching is already finished in appearance, it still remains histologically at the beginning of feeding. The fat loading of muscle varies quantitatively with growth, but there is no situational change for storage.

The content of fat in fish body at following three stages, that is those of 15 days and 25 days after hatching and at the beginning of feeding, shows a serial diminition in a following order, abdominal cavity, spinal cord, dorsal aorta, neighborhood of dark muscle, between both latero-dorsal muscles and dorsal fin.

In fish fed 1 month (Stage VIII, Fig. 9), concurrent with complete absorption of yolk, viscera have developed as well as adult. Assimilated fat from food is observed under antero-dorsal supracarinal muscle, between both latero-dorsal muscles, beneath the dark muscle, and it lies also between both latero-ventral muscles and in kidney in abdominal portion.

In fish body fed 2 months (Stage IX, Fig. 11), the amount of fat increased in every location. However, new deposition of fat was found posterior to ventral fins in abdominal portion. Tubular fat runs logitudinally surrounding a pair of medio-ventral infracarinal muscles.

After feeding for 3 months, no situational change of fat was observed in fish body (Stage X, Fig. 12). After a half year feeding, marked increase of fat content was observed in every site of fish body. Especially, abundant fat deposition was found between antero-ventral infracarinal muscle and ventral carinal muscle. Deep orange portions are shown under dorsal, adipose and pectoral fins (Stage XI, Figs. 13 and 14).

On the dorsal side of yearling fat-vein is seen around a pair of the anterior dorsal supracarinal muscle and it branches among many muscle situated near the basal region of the dorsal fin. The vein of fat surrounds the posterior dorsal supracarinal muscle at the posterior to that fin, it develops near the adipose fin, and attains to the tail region surrounding the posterior dorsal supracarinal muscle (Figs. 15～24).

Near the lateral line fat deposits in a large amount in and outside of the dark muscle, further it accumulates in a large quantity above and under the muscle described before, at near site of the lateral line nerve and in the dark muscle tissue (Figs. 18 and 19). On the ventral side the anterior portion of fat is seen like tubular appearance around the anterior ventral infracarinal muscle, branching among the muscle in the side of the ventral fin, and reunites at a circumference of the medio-ventral infracarinal muscle at the posterior to the ventral fin. At the situation just before the anal fin fat becomes again dendritic among the muscle being distributed thereafter in such a state to envelope the

posterior ventral infracarinal muscle. In a yearling fat storage is also distinct at a circumference of ventral ribs and intramuscular fat is remarkable in the abdomen, while it is scarce in the caudal region.

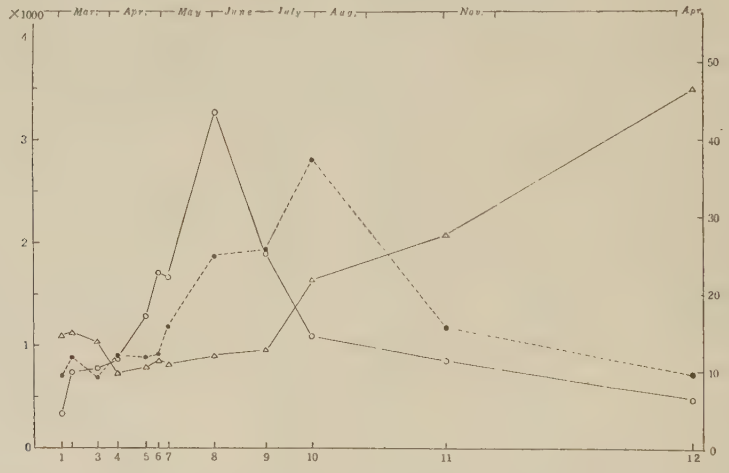
Table 2. Analysis of rainbow trout.

Stage	Part	Weight ratio to whole body or egg	Moisture %	Crude fat % dry matter	Phosphorus (P_2O_5), mg.% dry matter			
					Water soluble	Water insoluble	Ether soluble	Total
I	**Whole**		**54.2**	**14.6**	**330**	**707**	**11.9**	**1650**
II	**Whole**		**62.3**	**15.0**	**740**	**884**	**9.9**	**1630**
III	Embryo	15.1	81.5	46.9		892	61.3	
	Yolk	84.9	56.6	12.7		682	9.6	
	Whole		**58.3**	**13.7**	**782**	**697**	**11.1**	**1490**
IV	Embryo	39.1	86.4	24.8		451	68.3	
	Yolk	60.9	29.7	8.7		981	6.5	
	Whole		**43.5**	**9.6**	**884**	**902**	**10.1**	**1800**
V	Muscle	28.6	80.8	14.5		475	66.9	
	Head, etc	34.1	84.4	10.9		866	44.9	
	Yolk	37.3	48.6	9.3		901	17.0	
	Whole		**70.0**	**10.5**	**1290**	**885**	**38.1**	**2210**
VI	Muscle	43.0	81.2	10.1		737	39.1	
	Head, etc.	43.2	81.8	11.3		1200	126	
	Viscera	13.8	42.1	13.2		816	115	
	Whole		**77.7**	**11.3**	**1710**	**916**	**90.2**	**2720**
VII	Muscle	33.4	72.5	8.0		766	58.3	
	Head, etc	54.6	86.2	10.3		1630	163	
	Viscera	12.0	76.9	22.3		804	303	
	Whole		**80.5**	**10.9**	**1660**	**1180**	**133**	**5266**
VIII	Muscle	33.0	83.6	9.2		1100	72.3	
	Head, etc.	52.7	86.5	10.2		2750	149	
	Viscera	14.3	82.5	23.1		1030	152	
	Whole		**85.0**	**12.0**	**3260**	**1870**	**122.1**	**2980**
IX	Muscle	35.9	82.7	8.8		1030	72.3	
	Head, etc.	48.6	84.1	11.4		2990	182	
	Viscera	15.5	81.3	24.8		1110	79.6	
	Whole		**83.2**	**12.7**	**1880**	**1940**	**123**	**3950**
X	Muscle	36.8	81.2	14.1		3790	135.9	
	Head, etc.	46.1	83.6	22.0		3780	243	
	Viscera	17.1	76.4	35.2		877	61.8	
	Whole		**81.5**	**21.9**	**1110**	**2810**	**163**	**4090**
XI	Muscle	48.7	73.7	16.6		406	42.3	
	Head, etc.	35.9	70.5	27.8		2410	53.3	
	Viscera	15.4	69.9	54.4		346	31.8	
	Whole		**73.7**	**27.8**	**854**	**1180**	**45.5**	**2080**
XII	Muscle, ventral	10.9	65.3	49.1		598	4.9	
	ant. dors.	15.9	69.8	37.5		589	5.1	
	post dors.	19.7	73.9	22.3		650	3.4	
	caudal	7.2	74.1	19.9		820	1.4	
	total	53.7	71.0	33.2		639	4.1	
	Head, etc.	25.7	64.3	43.4		1240	11.0	
	Viscera	20.6	63.3	77.8		303	7.8	
	Whole		**67.7**	**46.5**	**474**	**731**	**6.9**	**1210**

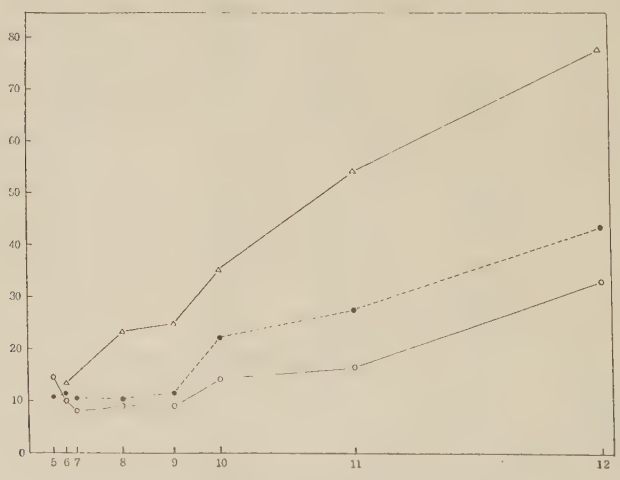
Chemical observations

1. Relations between growth and fat content

Each sample continued to diminish its fat content for a month to a hatching stage from an unfertilized one. After hatching, although feeding was started, the increase in fat was scarecely recognized till stage VIII, but the fat deposition occurred barely in a body passed a long period as three months or more after hatching.



Text-fig. 2. Contents of crude fat, water soluble- and insoluble phosphorus in rainbow trout. Left ordinate, phosphorus content in mg. % dry matter; right ordinate, crude fat content in % dry matter; abscissa, stage number; -○-, water soluble phosphorus; --●--, water insoluble phosphorus; -△-, crude fat.



Text-fig 3. Distribution of crude fat in rainbow trout. Ordinate, crude fat content in % dry matter; abscissa, stage number; -○-, muscle; --●--, head, bone and skin; -△-, viscera.

The appearance of depot fat in fish tissues occurred so rapidly that reached its content to 50% after one year feeding, and the body weight indicated so much as two hundred times of the first fingerling stage (Table 2 and Text-figs. 2 and 3).

2. Relations between the phosphorus content and the growth of fish.

a). Water soluble phosphorus

As shown in Table 2, the water soluble phosphorus increased rapidly at the stage of fertilized egg in twice amounts of unfertilized egg for only a week, and then the content of this type phosphorus rised day by day till the stage VIII. Going on more feeding, however, the phosphorus content was reduced unrespectedly and it indicated only 474 mg% dry matter in the end of one year feeding.

This type phosphorus contained the inorganic and organic compounds but was not separated in this experiment. Therefore, it was not evident in this experiment what type of phosphorus activates these physiological functions. However, in viewpoint of the activity of available phosphorus for the energy formation in animal tissue, we concluded that the development of rainbow trout will demand a remarkable amount of phosphorus.

b). Water insoluble phosphorus

This fraction containing various phosphorus such as one combined with protein, Ca-phosphate and the other compounds did not indicate so much changes in phosphorus content as in the water soluble type-phosphorus. At stage X the content of this type phosphorus gave a maximum value which came two months later than the case of water soluble phosphorus. Therefore, it will be supposed that the water insoluble phosphorus will be mainly used for the bone formation.

c). Ether soluble phosphorus

This type phosphorus is almost a constituent in phosphatides which is contained mainly in active tissues such as brain, liver and dark muscle in fish. It is, therefore, shown that these compounds in this experiment were contained in the tissue above mentioned. As same as with the water soluble type phosphorus,

Table 3. Phosphorus content of fat P_2O_5 mg% crude fat.

No. \ Part	Embryo	Muscle	Head, etc.	Yolk	Viscera	Whole
I						81.5
II						66.1
III	131			75.6		81.2
IV	275			74.6		104.7
V		460	412	183		296
VI		385	1120		872	798
VII		731	1580		1360	1220
VIII		791	1460		658	1020
IX		825	1590		331	971
X		969	1100		271	745
XI		270	171		70.0	186
XII		12.2	25.3		10.0	14.8

the maximum content of this type phosphorus was given at stage VIII, in which the content of phosphatide type phosphorus was just 15 times of unfertilized egg.

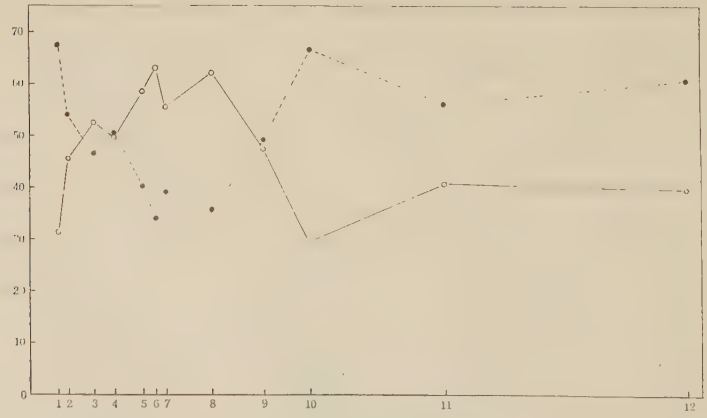
Distribution of phosphatide are shown in Table 3. Each content of phosphorus in brain and viscera indicated a maximum at stages VII—IX which will be the most active time in the life of fish.

d). Amount of phosphorus distributed in sample

Summing up each type phosphorus, it was shown that the content reached to a maximum in a month after the start of feeding. On the contray, the fat content at this period was near a minimum. The amount of each type phosphorus is shown in Table 4. From this data, it was evident that the translation on phosphorus was carried between the water soluble and water insoluble phosphorus at earlier stages during the development in rainbow trout (Text-fig. 4).

Table 4. Distribution of phosphorus, % to total phosphorus

No.	Water soluble	Water insoluble	Ether soluble
I	31.4	67.3	1.3
II	45.3	54.1	0.6
III	52.4	46.7	0.9
IV	49.1	50.1	0.8
V	58.5	40.0	1.5
VI	63.0	33.7	3.3
VII	55.3	39.4	5.3
VIII	62.0	35.6	2.4
IX	47.6	49.3	3.1
X	29.5	66.5	4.0
XI	40.9	56.1	3.0
XII	39.2	60.3	0.6



Text-fig. 4. Distribution of phosphorus. Ordinate, % to total phosphorus; abscissa, stage number; -○-, water soluble phosphorus; --●--, water insoluble phosphorus.

Discussion

Histological

A procedure of Baker partly amended by the authors and used in this study has brought the better result than the usual freezing method using no gelatin as is found in our previous work[14].

As dark muscle cells are stained deeper than pink muscle cells with Sudan III, it is recognizable that those contain the larger quantity of fat. The content of fat increases in corresponding to the growth of fish, while situations of fat storage do not almost change through the course from a sac fry to a yearling.

It is of interest to show the fact that the deposition of fat on the abdomen is later than on the dorsal side. On the abdomen at the posterior to the ventral fin, fat is found in a 2 month fingerling and at the anterior to that fin it is seen in a 3 month fingerling. On the dorsal side it is loaded already in a hatching fry.

Complete absorption of yolk takes place about 20 days later than the commencement of feeding. This fact suggests that the usual beginning of food supply would be a little earlier.

Chemical

In the development of rainbow trout, two interesting factors, fat and phosphorus, were distinct in their metabolic pathway each other. In the first place we can take up the diminition of fatty substances and the increase in phosphorus, especially the water soluble phosphorus. This fact demonstrates that the fatty substances are utilized as the source of energy which required for the promotion of the physiological functions such as fertilization, the formation of eyes, hatching, etc., and the increase in phosphorus is resulted from necessity of phosphorus as an activator in the formation of energy and a carrier of it.

Secondarily, we knew that the water soluble phosphorus was rapidly accumulated into tissue in a fertilization period. This will give the following suggestion the water soluble phosphorus must be more necessarily required for the accomplishment of complete development of fish than the water insoluble phosphorus which was recognized no accumulation in the tissue. To increase the phosphorus uptake notwithstanding no supply of food, phosphorus will be perhaps absorbed into cells from fresh water.

Summary

1. Rainbow trout was histologically and chemically studied at 12 stages during the development and growth.

2. Yolk vanishes in appearance in 25 days after hatching, but it fairly remains anatomically and seems need for about 20 days until its complete disappearance after commencement of feeding.

3. The deposition of fat is earlier on dorsal side and later on abdominal.

4. The loading of fat is most abundant on both sides of dorsal and ventral.

5. Although fat is contained in large quantity in the dark muscle cells, it is richer at the cephalic portion and decreases gradually towards the tail region.

6. Spinal cord of fishes in the stages from a larva, which is just after hatching, to a yearling is fairly rich in fat being stained in deep orange tint with alcoholic solution of Sudan III.

7. Chemically, what metabolism will be carried on fat and phosphorus during the development and growth of rainbow trout were studied.

8. The fat content diminished rapidly after a fertilization and then increased gradually after a start of feeding.

9. The water soluble phosphorus was accumulated during the fertilization and indicated a maximum content in the fingerling fed for a month, but diminished again following to the growth of fish. The water insoluble phosphorus, however, was little accumulated on that time, but after feeding indicated a maximum about two months later than the former.

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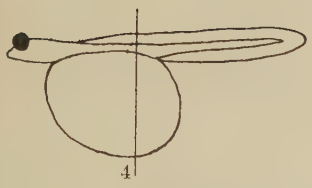

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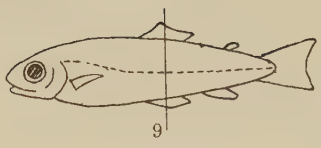

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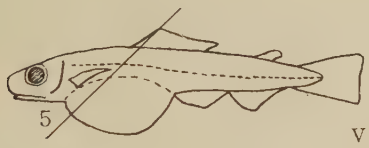

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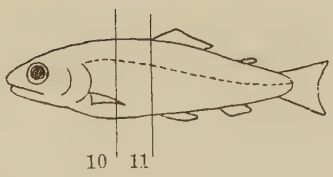

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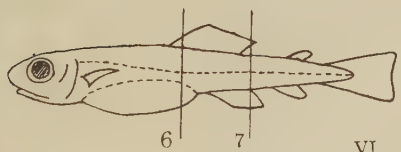

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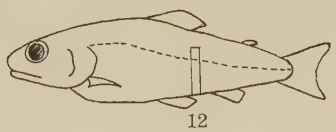

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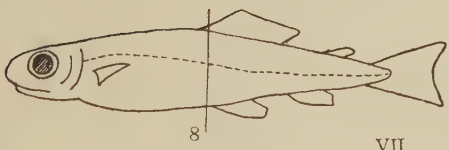

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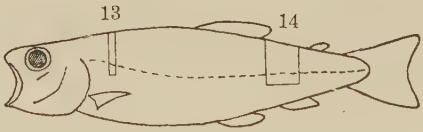

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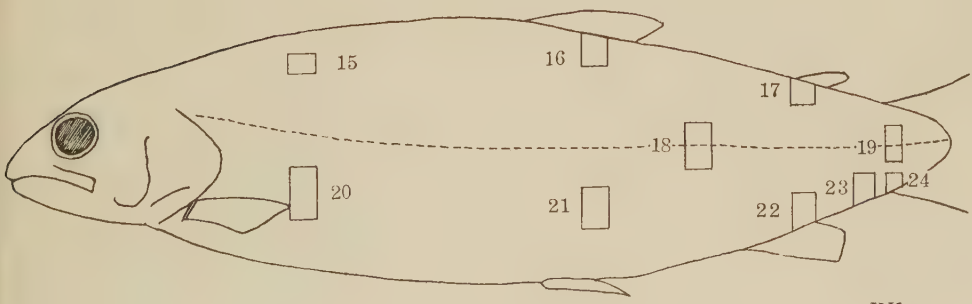


XII

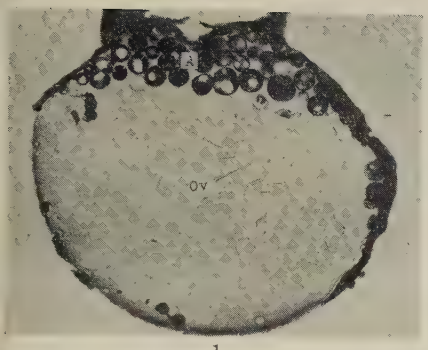
PLATES III—VII

Refer to the list of abbreviation and the text on the results of histological observation. Sections were made mainly transversally with the exception of Figures 14, 25–28, which were longitudinally sliced. Magnification is 10 times in all figures.

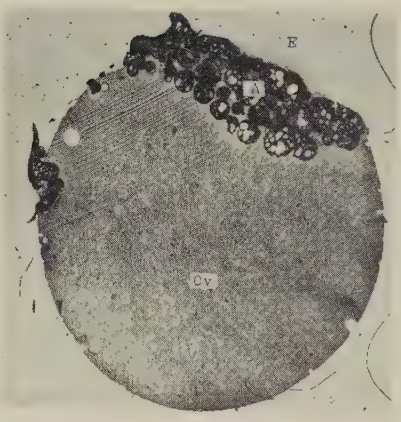
Plate III shows the sites of section by lines or closed small areas and denotes figure number in plates with the Arabic numbers. Roman type respectively indicates 12 stages, from unfertilized egg to yearling, of the sample used in these studies. Figures 25–28 in Plate VII denote the longitudinal sections of the stages IV (25 and 26), VI (27) and VII (28), respectively.

Abbreviations

A	Adiposus
Ad	Aorta dorsalis
C	Columna vertebralis
Ca	Cavitas abdominalis
Cu	Cutis
Cv	Costra ventralis
E	Embruon
En	Encephalum
H	Hepar
I	Intestinum
Kh	Kuniga histo
LI	Linea lateralis
Mcd	Musculus carinatus dorsalis
Mcv	Musculus carinatus ventralis
Mfa	Musculus flexor pinnae abdominalis externus
Mfdrd	Musculus flexor vel depressor radiorum pinnae dorsalis
Mfra	Musculus flexor radiorum pinnae analis
Miva	Musculus infracarinalis ventralis anterior
Mivm	Musculus infracarinalis ventralis medialis
Mivp	Musculus infracarinalis ventralis posterior
Mlae	Musculus levator pinnae abdominalis externus
Mlai	Musculus levator pinnae abdominalis internus
Mld	Musculus latero dorsalis
Mlerd	Musculus levator vel erector radiorum pinnae dorsalis
Mlra	Musculus levator radiorum pinnae analis
Mlv	Musculus latero ventralis
Mr	Musculus ruber
Ms	Modulla spinal
Msdr	Musculus supracarinalis dorsalis anterior
My	Myomere
Nl	Nervus lateralis
Oc	Oculus
Od	Organa digestiva
Oe	Oesophagus
Om	Os mandibulare
Ov	Ovoflavo
Pa	Pinna abdominalis
Pad	Pinna adiposus
Pan	Pinna analis
Pd	Pinna dorsalis
Pt	Pterygium
R	Ren
Ro	Rima operculi
V	Ventriculus


A
Ov

1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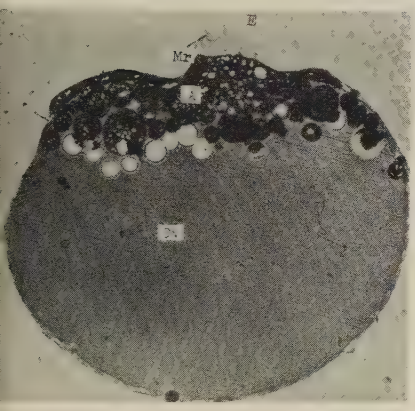
E
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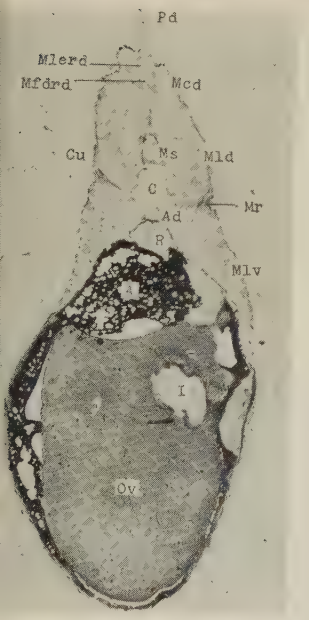
A
Pt

3

Pd
A
Mld
Cu
Mr
My
Mlv
A
Ov

4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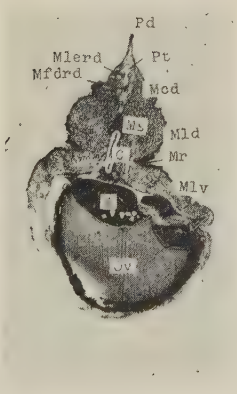
5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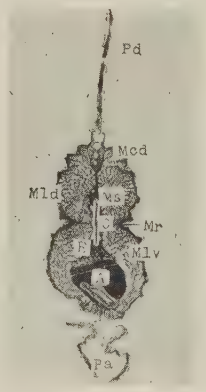
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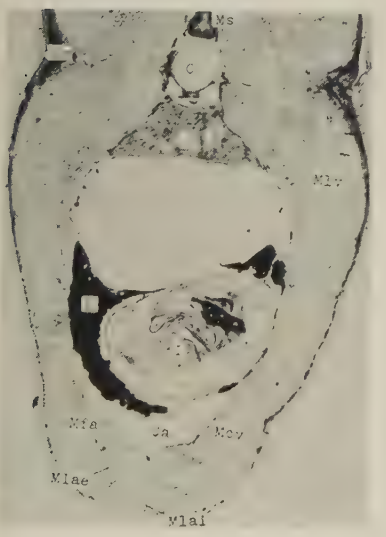

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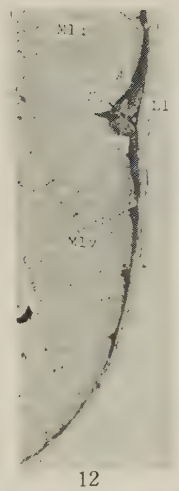

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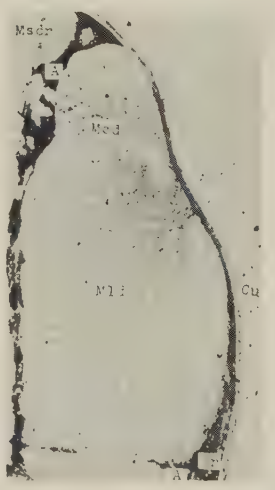

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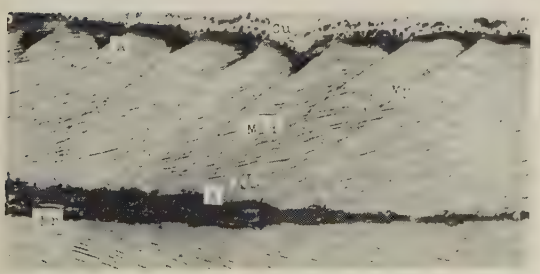

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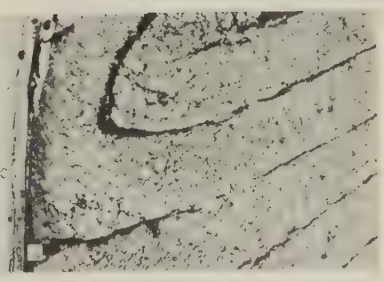

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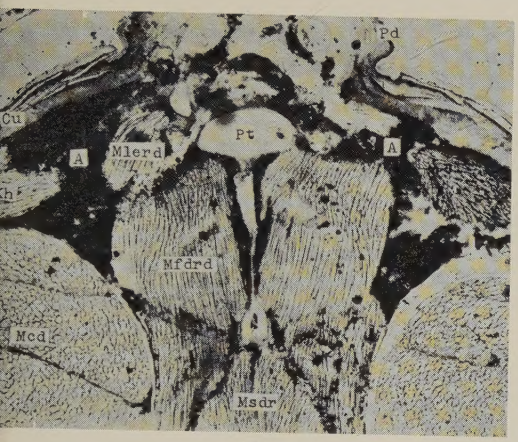

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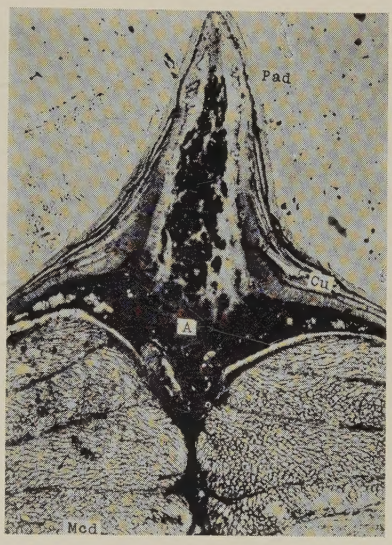

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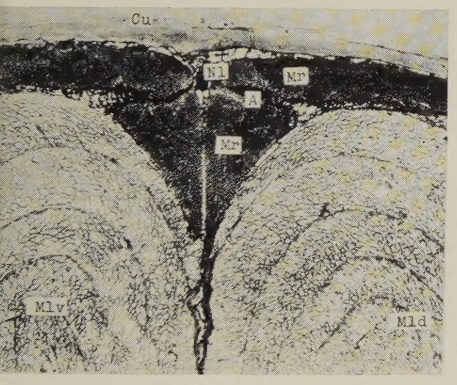

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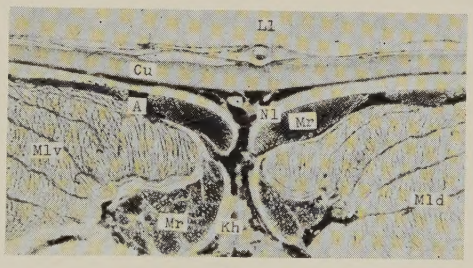

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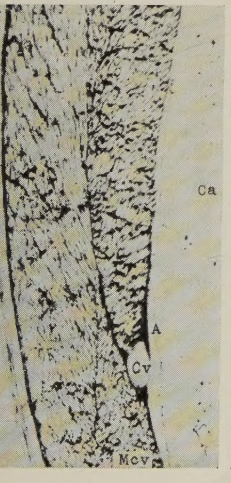

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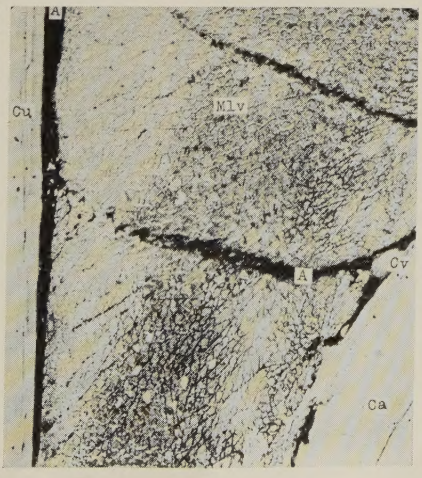

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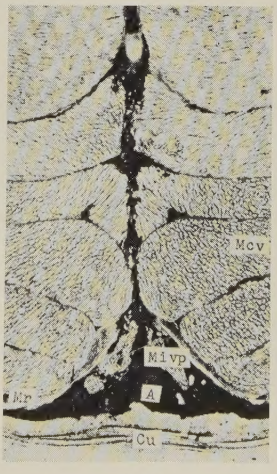

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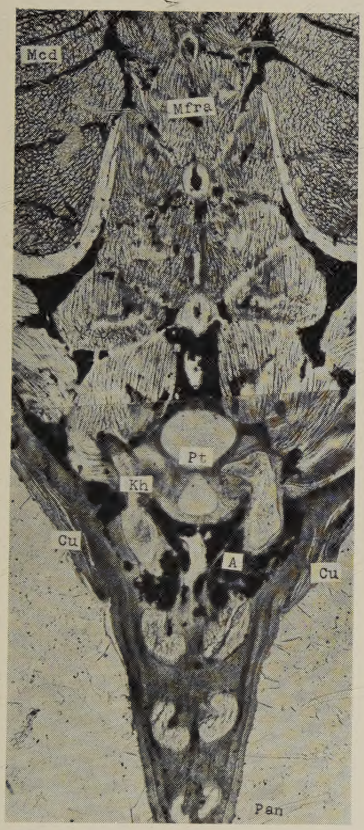

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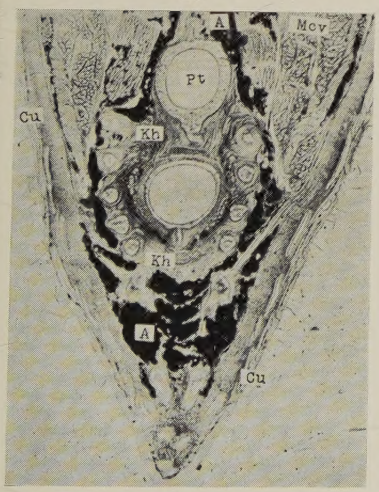

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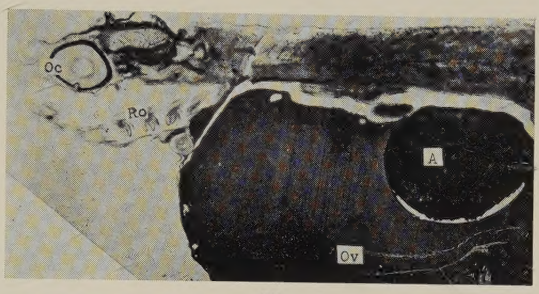

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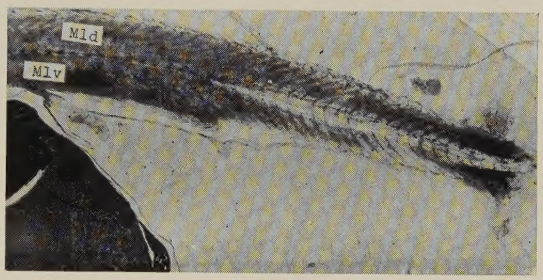

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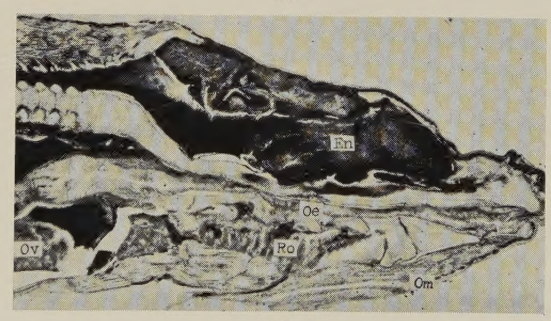

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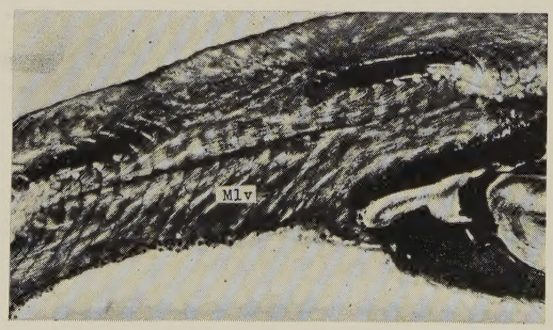

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